THE DISCOVERY OF ARCHAEOLOGICAL SITES:

A REVIEW OF METHODS AND TECHNIQUES

by

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A report prepared under the terms of U.S. Forest Service, PSW Grant No. 35, Pacific Southwest Forest and Range Experiment Station, Berkeley, California, June, 1980.

ACKNOWLEDGMENTS

Support for this research was provided by the Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, through PSW Grant No. 35. We gratefully acknowledge the assistance and support provided by the Experiment Station and its staff, and particularly wish to thank Benjamin Spada, Paul Guilkey, Richard Hubbard and Alice Ohara for their many instances of help.

We have been the beneficiaries of help from many dozens of colleagues around the country. During the past year, they have given us the fruits of their research and experience through correspondence, telephone discussions, interviews and meetings and scholarly conferences. While it is not possible to acknowledge everyone with whom we have discussed this study, there are a number of individuals greatly deserving our thanks. All others whose names do not appear here have our appreciation in equally great measure.

Paul W. Baxter, University of Oregon
Lowell J. Bean, California State University, Hayward
James Bellis, Notre Dame University
Polly Bickel, University of California, Berkeley
Robert Bonnichsen, University of Maine, Orono

Janet Brashler, Huron-Manistee National Forest, Michigan
James H. Cleland, Wirth Associates, San Diego
Michael B. Collins, University of Kentucky
Thomas J. Connelly, University of Oregon
Emma Lou Davis, Great Basin Foundation, San Diego

John R. Davis, Huron-Manistee National Forest, Michigan
Kathleen Deagan, Florida State University
Glenn De Garmo, Fort Bliss, Texas
Roger Desautels, Scientific Resource Surveys, Inc., Santa Ana
Roy S. Dickens, Jr., Georgia State University

Randolph E. Donahue, Michigan State University
Gerald X. Fitzgerald, El Paso Archaeological Society
David A. Fredrickson, California State University, Sonoma
Alan Garfinkel, Far Western Archaeological Research Group
Albert C. Goodyear, University of South Carolina

Ernestine Green, Regional Archaeologist, U.S. Forest Service, Missoula, Montana
Joel Grossman, Rutgers University
Judith Ann Halasi, Office of the State Archaeologist, Denver
Herrick Hanks, Bureau of Land Management, Washington, D.C.
Thomas R. Hester, University of Texas, San Antonio

Miley Holman, California State University, San Francisco
Keith Johnson, California State University, Chico
Douglas Jordan, University of Connecticut
Chester King, Society for California Archaeology
Linda B. King, California State University, San Jose

Tim Kohler, Washington State University
Makoto Kowta, California State University, Chico
Daniel Larson, California State University, Northridge
Valerie A. Levulett, Far Western Archaeological Research Group
Larry Loendorf, University of North Dakota

William Lovis, Michigan State University
Mark Lynch, Southern Illinois University
Kevin A. McBride, University of Connecticut
Marshall McKusick, University of Iowa
Francis P. McManamon, National Park Service, Boston

Alan McPherron, University of Pittsburgh
Donald S. Miller, Regional Archaeologist, U.S. Forest Service, San Francisco
Elizabeth A. Morris, Colorado State University
Jacqueline Nichols, Great Basin Foundation
P. J. O'Brien, Kansas State University

Stephen O'Brien, College of Marin
William Olsen, California State Department of Parks and Recreation
Max G. Pavesic, Boise State University
Christopher S. Peebles, University of Michigan
Fred Plog, Arizona State University

F. A. Riddell, California State Department of Parks and Recreation
Donna C. Roper, University of Missouri, Columbia
Jack M. Schock, Western Kentucky University
Marvin T. Smith, University of Georgia
Clay A. Singer, California State University, Northridge

S. Alan Skinner, Environmental Consultants, Inc., Dallas
Richard Stamps, Oakland University
Robert L. Stephenson, University of South Carolina
E. Gary Stickel, Environmental Research Archaeologists, Los Angeles
James B. Stoltman, University of Wisconsin, Madison

D. L. True, University of California, Davis
Robin Wells, California State University, San Francisco
Michael Whalen, University of Tulsa
Joseph C. Winter, University of New Mexico

W. Dean Wood, Southeastern Wildlife Services, Athens, Georgia
George M. Ziemens, University of Wyoming

I. INTRODUCTION

"The first priority is discovery..." (Schiffer, Sullivan and Klinger 1979:5)

The parallel growth of cultural resource management and regional research during the 1970's has brought archaeological survey to the forefront as a crucial arena of data collection. In this arena, fundamental issues of research goals, directions, philosophies, theory, method and techniques are being brought into examination, while governments and the archaeological profession struggle to cope with newly assumed responsibilities for the administration of the nation's cultural resources. Central to this struggle is knowledge of the nation's archaeological resources, which depends upon the ability of archaeologists to recognize and evaluate those resources. Resources undiscovered are resources unknown; not only can they not be managed, but they cannot contribute to the understanding of the past. Ignorance of them means not simply that they are uncounted, but that our knowledge is biased or skewed to the degree that the resources may otherwise be unrepreseted in our thinking. The discovery of archaeological resources, then, has a major place in the archaeological enterprise. The purpose of this study is to consider that place.

Some word about the source of this study will be useful in order to better understand the goals and directions of the study. This work was commissioned by the Pacific Southwest Forest and Range Experiment Station of the U.S. Forest Service in California. The Experiment Station had in mind some specific as well as general goals. It was interested in an overview of the current status of

archaeological survey, but particularly with reference to the mission the Forest Service held in California. The Forest Service, like all Federal land-administering agencies, has responsibilities for archaeological resources within its domain, and its ability to meet its responsibilities depends upon its knowledge of those resources. Knowledge of those resources is growing slowly and incompletely. Not only have most parts of the National Forests in California never been studied by archaeologists, the archaeological remains they contain are not reflections of the remains found throughout the state, so the research done elsewhere is not an entirely adequate guide to the archaeology of the mountainous forests. Knowledge of the forests' resources has grown slowly and somewhat haphazardly, as specific projects have caused surveys to be done in particular areas to varying degrees of intensity. Furthermore, the heavy vegetation characteristic of the forests has hampered survey. As is common in many regions, visibility is usually so poor that there is little way of knowing how well the discovered archaeology reflects the real archaeological resources of an area.

These problem areas present great difficulties for rational management of the National Forests' cultural resource responsibilities. It is partly a matter of cost. Archaeology is expensive, and administrators worry about attending to their responsibilities in ways that are fiscally most prudent and productive. Currently there are few widely accepted guidelines on costs and productivity in governments or among archaeologists. But another concern, and one that is at least as important as cost, deals with knowledge and rational decision-making from a basis of knowledge. In many ways, the evaluation of archaeological surveying resembles an algebraic

problem in which there are no values for any of the parts of the equation. The equation is symbolically instructive, but cannot be related to the real world. Administrators have been given the responsibility to compile inventories of cultural resources under Executive Order 11-593, in effect since 1972, and still cannot do so. According to the Random House College Dictionary, Revised Edition (1975), an inventory is, "...a detailed, often descriptive, list of articles, giving that code number, quantity, and value of each...a complete listing of merchandise or stock on hand...a formal list of the property of a person or estate...(p. 702)." This sense of inventory, of a complete listing or catalogue, is the sense envisioned by E.O. 11-593, and is the sense used by Forest Service administrators. Indeed, it is a rational administrative sense, because only on a basis of such knowledge can appropriate management policies and plans be made. It is possible to make an inventory of the trees in a forest through a sampling or a census, but it is not possible to obtain an archaeological inventory using traditional methods because there is no way to measure or estimate reliably what has not been counted.

There are other pragmatic reasons for an interest in archaeological survey as well. When surveys fail to identify sites that later are discovered during construction or other land-use activities, it not only creates management problems, unanticipated expenses and delays, and ill-will, but it also indicates the inadequacy of the original survey. If these problems can be reduced or eliminated through improvements in archaeological survey procedures, the investment will justify itself.

The Experiment Station, then, had several reasons for wanting a study of the current status of archaeological survey methods and techniques with respect to site discovery. This study is particularly concerned with these matters as they relate to California, and in particular to the kinds of archaeological resources found in the National Forests in the mountains of California. However, the problem of site discovery during survey is one which is perceived nationwide, so we hope that the study will have some interest outside the state.

We should note that some important studies of aspects of archaeological survey have appeared within the past few years. King's 1977 manual on survey for cultural resource managers (T. King 1977) uses a hypothetical valley setting as a vehicle to discuss problems and possible solutions in resource management situations. "Decision Making in Modern Surveys" by Plog, Plog and Wait (1978), and "The Design of Archaeological Surveys" by Schiffer, Sullivan and Klinger (1979) discuss a variety of methodologocal and theoretical issues concerning surveys. None of these studies deals very substantively with issues and problems concerning site discovery, however. The last two papers, in particular, refer especially to large-scale, heavily-funded projects. It is in such mega-surveys that methodological sophistication can be most readily displayed, but as Glassow (1979) notes, the great majority of surveys done around the country are studies of a 300-foot-long road realignment or a four-acre land use study. A project budgeted at $500 cannot make use of expensive labor or high technology, no matter how desirable it may be. Similarly, many of the issues raised by these papers, important though they are, simply cannot be easily related to the needs of many small-scale

survey projects. Yet the difficulties of site or archaeological resource discovery are as pressing to small-scale projects as to large ones.

That there is a problem in the discovery of archaeological sites or resources has been recognized for some years, mainly by archaeologists living in the eastern United States. There, luxurient plant growth prevents the surveyor from observing the surface of the ground in many cases, so the traditional means of discovering the existence of resources is not successful. Eastern U. S. archaeologists have employed a number of strategems to overcome this problem, and in the process have developed a considerable body of knowledge and experience. Much of this information is not very widely circulated. It has developed largely through the performance of contracted research, and descriptions of the research have been described, with few exceptions, in reports submitted to the contracting agencies but not circulated elsewhere. Many archaeologists thus are not benefitting from each others' experiences, and are independently undergoing the same trial-and-error efforts as their colleagues. Because of the general non-circulation of the results of contract archaeological research, many scholars are not very aware of the magnitude of experimental efforts to overcome problems in site discovery. However, they have been very willing to share their own efforts with us in the hope that it will help such knowledge become more widespread and help others.

THE NATURE OF ARCHAEOLOGICAL SITES

As usually conceived, the target of archaeological survey is a unit called an archaeological site. Deetz (1967) defined a site as a location at which archaeological remains are concentrated. His operational definition, reflecting long-held understandings among archaeologists, is widely accepted. It offers a useful framework for the management of lands within which archaeological resources occur. As "new archaeologists" have been fond of saying for years, human behavior is patterned rather than random, and therefore does not take place randomly throughout the environment. It is concentrated in particular locations and in particular ways at locations, and the physical residues of such behaviors create non-random distributions of remains in the environment (Woodall 1972, for example). Locations where such remains are concentrated can be defined and delimited for management purposes, freeing the rest of the environment for management toward other purposes. The concept of a site as a discrete locus of archaeological significance has a great deal of appeal and utility for the administrators of cultural resources. It also is useful for the pursuit of a number of kinds of research problems. Ever since Binford called for the study of regional research problems (Binford 1964), archaeologists have used the unit of the site as a focus for multi-site research as well as the traditional unit within which excavation takes place: for example, Higgs and Vita-Finzi (1972) stimulated the use of catchment analysis with the site as a center, and Hodder has stimulated the use of locational analysis with sites as fundamental units (Hodder 1978; Hodder and Orton 1976). Thus we find the site remaining a

basic analytic and management unit, with the meaning as given by Deetz (e.g. Hole and Heizer 1977:388; Knudsen 1978:488).

There are, however, certain limitations to the concept of the site. One concerns the meaning of a site as a locus of human behavior. The other concerns its meaning as a locus of archaeological remains.

Schiffer (e.g. 1976) has called to question the view of a site as a place where human behavior has produced material consequences which we call a site. He does not mean to say that sites are not produced by human beings through behavior, for invariably they are. Rather, he argues that the logic that accounts for the structure of human behavior is different from the logic that accounts for the structure of archaeological remains in the ground. Any particular set of remains might have been produced by any of several alternate patterns of behavior. Similarly, any given set of human behavior might produce any of an array of different patterns in the material archaeological record. There can be no direct correlation between one system of patterning and the other. Each needs to be analyzed separately according to an appropriate logical system. It is inappropriate, therefore, to define material sites in behavioralist terms even if sites ultimately have behavioral sources. We can more usefully consider sites from a more purely materialist, mecahnical perspective, just as we can study such subjects as the mechanics of the human body without regard to the psychology of the mind while not denying the importance of psychology for other purposes.

In a development more central to the present subject but still related to Schiffer's point, some archaeologists have called the concept of a site as a physical locus of remains into question.

Both D. Thomas (1975) and Goodyear (1975), for example, have discussed the idea of "non-site sites" based on their own field experience.

The term "non-site site" is an obvious contrdiction in terms, but it has some importance for archaeological survey. Both Thomas and House did their field work (in this case) in the Southwest, where the idea of an archaeological site was strongly conditioned by the kinds of large, permanent settlements that occurred in the region in prehistoric times. Pueblo ruins in the Southwest and sedentary village sites in California offered models of sites that were physically large and obtrusive, with dense concentrations of artifacts and features within fairly easily defined parameters. Following this model, the Southwestern Archaeological Research Group (SARG) used as a definition of a site "any 'locus of cultural material, artifacts or facilities' with an artifact density of at least 5 artifacts per square meter (quoted from Plog, Plog and Wait 1978:387)." This definition is pleasing because it is objective and quantifyable. However, in operation it became somewhat difficult to use because very few loci that archaeologists would ordinarily call sites could meet the density criterion. As researchers found on Chevelon Mesa, Arizona, and Black Mesa, New Mexico, 95% of the sites found were not sites according to that definition (ibid.).

When Thomas began to study the archaeology of the Reese River drainage in central Nevada (1975), he discovered that not only did none of his sites have high artifact densities, many did not have any discrenable centers of artifact concentration at all. Instead, they were areas within which low numbers of artifacts occurred as scatters. Some of these scatters, he found, rather than having any measurable

boundaries, simply continued on out toward the horizon, with artifacts becoming gradually less and less dense but never becoming totally absent. In addition, Thomas found numbers of isolated artifacts scattered about the landscape. His findings did not fit the traditional concept of a site as a place of concentrated artifact and feature occurrence with a distinct center and discrete boumdaries, and yet it reflected the archaeological remains of a traditional way of life so it was an important archaeological record. Goodyear, working in Arizona, had similar findings. They therefore evolved the idea of "non-site sites" to describe the data they encountered.

The concept of non-site sites is a logical and analytic anathema, however, so archaeologists have attempted to circumvent it. The goal of archaeological survey is being redefined by some workers from the search for sites in an area to the discovery and recording of the <u>regional archaeological record</u>: the distribution of archaeological remains in a region (see Schiffer, Sullivan and Klinger 1979:2, for example). Another approach is the redefinition of the concept of site, to mean a locus at which any archaeological remains occur, without regard to density, centers or boundaries. In this approach, our concepts of the variety and classification of sites changes but the analytic unit of a site as a spatial location bearing archaeological remains is preserved. It is possible under this definition to regard the occurrence of a single isolated artifact as a "site." Indeed, some researchers have found that excavation at loci of single, isolated artifacts has periodically revealed the existences of large, rich, dense sites (Munson and Munson 1979). Thus,

> the presumption of the unimportance of isolated artifacts

is unjustified whether one is concerned with what a locus can say about the past or with the significance of one piece of data to predict the occurrence of others (Moratto and Kelly 1978).

Whether one modifies the meaning of the term "site" or abandons it to focus on smaller-scale units of archaeological observation, the goal of archaeological survey remains the same: the discovery of the nature, variety and distribution of archaeological resources within a region. This definition provides a means to define the archaeological survey itself. Following Schiffer, Sullivan and Klinger (1979:2), an archaeological survey is the application of techniques to achieve this discovery. The management of survey research and the development of survey design therefore involves the evaluation of the kinds resources likely to be found in a region, the conditions under which the search is to be conducted, and the array of techniques available for the search, in order to select the search strategy best suited for the circumstances. The Forest Service has a particular concern for the improvement of the productivity of searches while at the same time striving for greater cost-effectiveness in its expenditures. This discussion tells us that the route to achieving these ends lies in the examination of the characteristics of alternate discovery or search techniques so that they can be measured in the context of particular settings and predicted archaeological remains.

THE PROBLEM OF DISCOVERY:

Survey is as difficult an archaeological management problem as it is because the discovery of archaeological remains is not the straightforward matter that textbooks have assumed it to be. If one reads traditional manuals of archaeological methods and techniques,

such as Heizer (1959), one finds that the subject of site survey is treated as a matter of reading maps and filling out recording forms. It is assumed that site discovery depends on the observation abilities of the archaeologist; if a site exists, in general there will be some visible manifestation of it, and all that is required is a sharp-eyed archaeologist equipped with boots, compass, topographic map and recording form for the site to enter the body of scientific knowledge. Even more recent texts, such as Hester, Heizer and Graham (1975), Hole and Heizer (1977), Fladmark (1978), and Knudsen (1978) tend to follow this assumption, except that they add the need to consider sampling in the selection of areas to search for sites.

It is possible, of course, to encounter many archaeological sites or remains simply by walking around and looking, if the observer knows what to look for. That is how most recorded sites came to be discovered. As Plog, Plog and Wait demonstrate (1978:389-394), in general the ability of archaeologists to find sites varies directly with the time spent looking. If time alone were all that was required to improve the discovery of archaeological remains, the problem would be easily solved. It is not, however.

Connolly and Baxter (1980) have an interesting discussion of two Class II inventory surveys done in southern Oregon for the Bureau of Land Management. In one wilderness area of about 4000 acres, a traditional survey made by walking surveyors who studied carefully selected study tracts produced not a single archaeological site. Another survey of a similar, nearby area of the same size made use of subsurface exploratory techniques as well as traditional searching by walking surveyors, and identified 61 sites. It must be assumed

that the area with no recorded sites also contains several dozen sites, and that the failure of trained surveyors to find them has more to do with the way they looked than with the presence or absence of sites.

This example might be passed off as a chance occurrence, except that it has become a common occurrence around the country. In two surveys of adjacent and similar sections of freeway routes in South Carolina, one survey found six sites and the other found over 40, with survey methods the only significant difference (House and Ballenger 1976). In our own survey of 29 miles of proposed road route for the GO Road in northwest California, a previous survey of the routes had found no sites using only traditional methods, but we were able to locate 13 sites along the rights-of-way through the use of a raking technique to clear the forest duff (Theodoratus et al. 1979; Chartkoff and Donahue 1980). Many more examples could be given, but the point is made that the discovery of archaeological remains is not simply a matter to be resolved by dispatching trained observers to walk over the landscape in search of them. A variety of factors can prevent even the most skilled searcher from locating sites. Yet the literature of archaeological survey still tends to treat site discovery as a given rather than as a central problem. Frank McManamon has expressed the problem succinctly:

> Although many archaeologists have recognized the importance of explicit and rigorous sampling procedures, choosing appropriate field techniques, and using extant information to predict site locations, the majority of analyses addressing these points come from a few small areas of the world such as the U.S. Southwest and the Mexican highlands. The sparse vegetation and relative absence of soil aggradation in these areas are rather unique conditions. In vast areas throughout the world, dense vegetation and soil conceal archaeological sites. Examinations of the effectiveness and costs of different sampling pro-

> cedures, background information analysis, and field techniques in such areas is just beginning. The development of effective and efficient methods and techniques is a pressing problem for contemporary archaeology (McManamon 1980:2).

Not only do dense vegetation and surface vegetation litter obscure many archaeological sites, other factors also complicate the site discovery problem. Natural factors such as alluvial and aeolian deposition, landslides and rising sea levels, and cultural factors such as expanding urbanization, farming and relic-collecting all serve to obscure many sites from view. With certain exceptions, sites that are hidden from view will not be discovered by passing surveyors, so they will not be represented in site files, management decisions or research findings. Studies that ignore such sites are inherently biased. Their results reflect an erroneous understanding of the nature, structure and meaning of a region's archaeological record. The magnitude of the bias depends on the nature, quantity and distribution of the undiscovered remains. It varies, obviously, from place to place according to the nature and degree of hidden archaeological remains. In areas where most sites are exposed, the bias is small and probably is easily corrected. Most parts of the United States are not so blessed, however, and even the magnitude of the bias is unknown. As the surveys cited earlier suggest, however, in a number of cases the hidden sites greatly outnumber the known ones. Any time a variance exceeds its sample, there is little hope of making valid predictions from the sample.

The kind of remains that remain hidden from traditional surveys varies, of course, from situation to situation. In general, however, it can be predicted that smaller, less dense artifact concentrations will be missed more readily by surveys than large, rich, dense ones.

Fred Plog (1974; Plog and Hill 1971) found in his survey of the Chevelon Mesa of northern Arizona that there tended to be an inverse relationship between site size and site frequency. Small, low-density archaeological concentrations tended to greatly outnumber large, rich, dense concentrations. We have found similar patterns in a number of our surveys in the mountains of California (where California's national forests are located). The great preponderance of archaeological remains occur in small, simple, low-density concentrations. If a survey there identifies only or mostly large and dense concentrations, it is most likely that most of the concentrations in the particular study area have gone undetected (e.g. Chartkoff and Chartkoff 1975; Chartkoff, Chartkoff and Kona 1967; Chartkoff and Childress 1966; Chartkoff and Ritter 1966; Theodoratus et al. 1979).

Other surveyors have made similar findings elsewhere, although the degree to which small, low-density concentrations predominate varies from place to place. Examples include Brooks and Scurry (1978) in South Carolina; Bruseth et al. (1977) in Texas); DePratter (1976) in Georgia; Goodyear (1975) in Arizona; Hanes (1978) in Oregon; Hanson and Most (1978) in South Carolina; Ives (1977) in Missouri; Keller (1980) in Louisiana; Lovis (1976) in Michigan; McManamon (1978) in Massachusetts; Munson and Munson (1979) in Montana; Nash (1975) in Manitoba; Reher (1977) in New Mexico; Rubenstein (1980) in Virginia; Schiffer and House (1975) in Arkansas; Scott, McCarthy and Grady (1978) in Texas; D. Thomas (1969, 1975a) in Nevada; Thorbahn (1980) in Connecticut; Trubowitz (1973) in New York; and Whalen (1977) in west Texas, to cite but a few examples. Such studies demonstrate that, even in less-than-ideal survey situations, thorough surveys often show

there to be a preponderance, frequently a vast preponderance, of small, simple, low-density archaeological concentrations.

The implication of this situation is that such small sites or concentrations are the ones most likely to be missed when survey conditions are less than ideal. The result would be a body of data biased in terms of too few sites, of sites whose average size is too large, and of disproportionately few smaller sites. Since smaller sites tend not to occur in the same settings as larger sites in many cases, interpretations of settlement distributions and frequencies would be correspondingly biased, and management decisions about land use would be similarly misinformed. Rare types of small sites are likely to either be missed altogether, or to appear to be far more common than they really are, while more common types of small sites are likely to be under-represented in frequency and distribution in proportion to the bias of the survey as a whole.

Archaeologists have tended to pay comparatively little attention to small sites, yet they provide much potential information. First, since they usually are simple (and behaviorally reflect few kinds of activities per locus), they display less redundancy and confusing "noise" than more complex sites which may aid analysis. In addition, a society which uses multiple sites in its total existence (and virtually all societies do) does not necessarily reduplicate all activities essential to its existence in every site it uses. To the contrary, many activities not performed in large, complex sites are performed at small, remote sites. Small sites are not invariably poor, simplified versions of larger ones. They may, and often do, different, unique sets of activities that may have no other archaeological manifestation. Small sites, though individually simple in

content and structure, may nonetheless be more varied from one to another than are larger, more complex sites. Furthermore, in at least some cases an important aspect of knowledge concerning small, simple sites concerns their location and number. In some cases, locational attributes may be even more revealing than morphological ones (e.g. Chartkoff and Donahue 1980). Surveys which fail to reveal such small, simple sites in their proper frequencies and distributions may therefore be contributing serious biases to the understanding of a region's archaeology, biases that cannot be corrected by the more intensive study of larger, more complex sites.

But small sites are not the only ones subject to being obscured in surveys. Urban development, which has often peaked in areas which also saw climax prehistoric settlement, may mask over sites of all sizes. For example, the U.S. Southwest is often regarded as the most optimal area for archaeological survey because of its sparse desert vegetation. However,

> Despite the fact that the ground surface in the Southwest is said to be unobscured, it is. In the Phoenix area, the major Hohokam sites were said to be destroyed until we began looking and determined that underneath the plow zone, sidewalk (or) whatever, a great deal remains (Fred Plog, personal communication, Tempe, 1980).

Deagan (1980) has had similar experiences in urban St. Augustine, Florida, as have Carnes and Dickens (1979) in Atlanta, Georgia. Even very substantial archaeological concentrations may be totally obscured from surface view by modern urban development. Major sites lie buried beneath virtually every modern city in North America.

Even in rural areas, even major sites may be fully obscured from surface view. For example, in precolumbian times river valleys were the locus for many of the largest sites in the nation (e.g. Phillips,

Ford and Griffin 1951). Yet many river valleys have been subjected to repeated flooding and alluvial deposition within the last century, especially as modern land use has led to increased runoff and erosion. Deposits up to 10 m. or more thick may overlie the land surfaces used only a few centuries ago, effectively obscuring major sites (e.g. Taylor and Smith 1978; James Bellis, personal communication, West Lafayette, 1980). In western North America, the entire community of Ozette was buried by a mud slide only a few centuries ago (Kirk and Daugherty 1978). Even though major sites tend to be less common than smaller concentrations, size alone does not insure their identification. Some recent surveys have begun to reveal the existence of substantial sites in unsuspected settings, such as mountain slopes (e.g. Bickel 1978; Theodoratus et al. 1979). The reason that the sites were unanticipated is that the existing knowledge base, biased as it was, did not indicate that such sites should occur.

This discussion points out that archaeologists face a very real problem in the discovery of archaeological sites or remains. Schiffer, Sullivan and Klinger (1979:4-10) discuss five factors that affect the probability of a site's discovery: abundance, clustering, obtrusiveness, visibility and accessibility. Although we wish to avoid the repetition of available work as much as possible, it is useful for our discussion to synposize their definitions and to add some observation of our own.

Abundance: abundance refers to the frequency of archaeological remains in a unit of land, and can be expressed as a number or as a density ratio of loci to land area. In general, any area has many kinds of remains and there may be marked differences in the abundance of

different kinds of remains. If all else were equal and ideal, the probability of a site's discovery should vary according to the abundance of its type, and therefore according to the intensity of a survey. Common or high-frequency site types are more likely to be found, and are more likely to be found in proportions approximating their true frequencies and distributions, all else being equal, than rarer types of sites. Rarer site types are less likely to be found, but if found, are going to appear to be more important numerically and typologically than they really are. This is one of the reasons why large sites, which tend to be rare, are made more of than they warrant. The situation is somewhat comparable to sampling for rare genes in genetics, such as the Sewell Wright Effect in genetic drift (c.f. Campbell 1977, for example).

Clustering: clustering refers to the degree to which archaeological remains covary in space or are spatially aggregated. Archaeological remains are never uniformly distributed over space. Individual remains tend to be aggregated, to greater or lesser degrees, in particular loci, producing various kinds of sites, and these sites or aggregation loci themselves, as well as the remains within them, tend to display greater or lesser degrees of aggregation with other loci or with ecological variables. Flake scatters in wilderness areas often tend to display comparatively low degrees of clustering, while large village sites tend to exhibit comparatively high degrees. If all else were equal, the probability of site discovery varies inversely with the degree of clustering. Schiffer, Sullivan and Klinger (1979: 4-5) point out that when sites have both high clustering and low abundance, probabalistic sampling tends to be an ineffective strategy for discovering them.

The clustering phenomenon has certain implications for survey strategy. It suggests that ANY systematic, low-percentage sampling strategy, whether random or interval, is a low-probability means to discover a representative sample of highly clustered sites. The added factor of low abundance, of course further reduces the odds of discovery, since any rare site has less chance of encounter (all else being equal) than an abundant type.

Obtrusiveness: obtrusiveness refers to the degree to which a given archaeological remain can be detected by a particular technique of observation. Taylor and Smith (1979:179), for example, cite the Temple of the Sun at Teotihuacan (probably meaning the Pyramid of the Sun) as a highly obtrusive site or feature, since it covers 13 acres and is over 200 ft. high. This example does not convey the idea of a technique-specific degree of obtrusiveness, however, since it is hard to imagine any realistic survey conditions under which the pyramid would NOT be highly obtrusive. We could cite the desert intaglios or rock-alignment figures of Nazca, Peru, as a more technique-specific case. The Spaniards walked over the desert figures for several centuries without knowing they were there, because they are almost impossible to perceive from the ground. Not until the advent of aerial photography in Peru during the 1920's was their existence made generally known.

The degree of obtrusiveness of a site for a survey technique affects the probability that it will be discovered during a particular kind of survey. If observation during walking (pedestrian survey) is the only discovery technique used, only those sites with high obtrusiveness to surface visual examination will have a high probability of dis-

covery, all else being equal. Such sites often tend to be characterized by such attributes as high artifact density at the surface, above-ground structural or physical remains, large surface areas, or visually distinctive soils. Sites or loci that are small, with low density of remains and simple, non-protruding structures, have comparatively low obtrusiveness for pedestrian survey regardless of their abundance or degree of clustering, which is why so many small flake scatters go undetected.

Visibility: visibility refers to the capability of archaeological remains to be detected in the face of environmental factors that obscure the remains from view. We have already noted the kinds of cultural and natural factors that can serve to obscure sites from view. It should be mentioned that visibility (or its converse, obscurity) varies by degree rather than in absolute terms, so it can change dramatically within a single study area, even within a single environmental stratum within a study area. Plant covers such as brush, grass, ferns or leafy forest-floor broadleaf plants can vary to the degree to which they blanket the ground from zero to 100% depending on a host of natural factors, for example. Visibilty is a locus-specific phenomenon and needs to be assessed in the field rather than decided beforehand.

In general, small sites are more readily obscured than large ones, and sites of low obtrusiveness are more easily obscured than those of high obtrusiveness, another reason why flake scatters are so hard to find in their true numbers. However, even monumental sites can be obscured by natural conditions. Macchu Picchu, and pyramids in the Mesoamerican lowlands, demonstrate this point.

<u>Accessibility</u>: accessibility refers to factors that affect an observer's ability to reach a place. Accessibility may be conditioned by environmental factors, such as terrain, road access, climate, vegetation and animal life, and by cultural factors such as land ownership patterns and field crew morale.

<u>Other Factors</u>: the factors discussed above are properties of sites and their environments, by and large, which affect the probability of their discovery. There are a number of other factors that also influence site discovery. For example, sites that have been surface-collected by relic collectors may not be identifiable from surface remains. Rainfall makes surface stone tools easier to see. Factors such as artifact density at the surface govern obtrusiveness. However, we wish to focus on three other factors in particular that strike us as being important, especially with regard to cultural resource management surveys: intensity, ability and funding.

<u>Intensity</u>: intensity refers to the size of sample and the rigor with which site searches are conducted. It can be varied in different ways through the adjustment of time and labor. For example, the larger the size of a sample surveyed with a given technique, the greater the probability that site discovery will occur (Schiffer, Sullivan and Klinger (1979). The more time that is spent within a single area, the greater the probability that remains within the area will be encountered (Plog, Plog and Wait 1978). The more times a locus is visited, the greater the probability that remains at the locus will be discovered (Bickel 1978). The more search techniques that are used over an area, the greater the probability that remains

present will be identified (Ives and Evans 1980; Ives and Garrison 1977).

Ability: ability refers to the skills of surveyors. This subject is one which archaeologists have been reluctant to discuss openly; Plog, Plog and Wait (1978) offer an important exception, in which they present experimental results of tests of the abilities of different individuals and crews. Taylor and Smith (1978) coped with the problem through personnel rotation.

All individuals differ to some degree in skill level, but adequate training is presumed to provide a base level of competence, and such schemes as weighting factors and crew rotation may be adequate to control for quality variance among personnel. In general, most surveys do not report having estimated or controlled for such factors. Since most survey projects are small and have few in-field personnel, the ability to control for such variables may be more ideal than real, yet the presence of such variance can greatly skew project results.

An interesting emerging problem in many parts of the country concerns the creation of corps of trained individuals who possess whatever baseline skills are needed for survey. Contract archaeology is conducted under the assumption that work is done by crew members who all possess at least base line skills. The traditional means to provide this corps of trained individuals has been the archaeological field school, usually done during the summer through surveys and excavations that are used to provide original training experiences. In the past, the staffs of research projects were drawn from the body of field school graduates. More recently, however, the growth of environmental impact studies has changed this

situation. The availability of support through contracts has drawn many researchers from the field school program. At the same time, the rapid growth of contract archaeology has created a demand for large numbers of field workers. California is one area where field work has expanded rapidly while field schools have almost disappeared. The result is an interesting conumdrum: contractors must field trained crews while the source of trained personnel is disappearing. Presumably, contract work is not the place to provide on-the-job training, although this must be the inevitable result if work levels are to be maintained. This situation promises to complicate the problem of field worker ability.

A third factor adds yet more complexity to the problem: crew morale. Contract archaeology, principally survey, has moved to embrace predictive sampling strategies. As many archaeologists realise, one of the consequences of the use of predictive sampling in survey situations, whether the sampling involves searching or some form of sub-surface testing, is that many search units must prove sterile. For example, we recently completed a survey in which forest duff clearance was done in about 3000 ten-foot-square quadrats, of which only 13 units contained archaeologically significant remains (Theodoratus et al. 1979). While this example is somewhat extreme, the non-random distribution of most archaeological remains insures that random sampling or interval sampling programs must yield many sterile units. Our experience with crew psychology is such that we find even highly-trained field workers suffer from morale problems when faced with large numbers of fruitless (from the data-collection standpoint) searches, and that it is difficult under the circumstances for crew members to maintain high levels of attention and concentration

throughout a field season. We know from conversations with many colleagues that our experience is not unique. The result is the variation of worker quality, not only from individual to individual, but in the work of one individual, over time. This problem can be partially controlled by variation in tasks, if project time, scope and support allow. Still, it is a meaningful problem for the quality of research, and one that the discipline has not yet treated very seriously. Such variations in work quality can result in the non-recognition of remains that otherwise should have been recognized.

Funding: funding refers to the financial support available for a survey. The level of funding obviously affects the quantity and quality of survey work, and this factor might seem so self-evident that it does not deserve mention. In light of the emphasis of some commentators on cost-effectiveness, however (e.g. Schiffer, Sullivan and Klinger 1979), some comment is needed. It is not simply that larger budgets allow for more intensive surveys and therefore the discovery of more sites; such may or may not be the case for any particular project. Of more relevance is Glassow's point (1979) that most projects are small in scale: small survey areas, small crews, small budgets and short time periods. In the national forests of California, for example, for every project budgeted at $50,000 or more, there are dozens of small timber sale surveys (Donald S. Miller, persomal communication, San Francisco, 1980). The archaeological remains that may occur within a small timber sale or exchange tract need and deserve proper management as much as the remains that may occur within large study tracts. Their proper management, however,

depends first on their discovery. Discovery depends upon the adequacy of the search for them, and in general small-scale surveys suffer disproportionately in quality from small budgets, crew sizes and time periods. The loss in quality is more than proportional because many needs cannot be met through a scaled-down budget. There are lower limits of time allowance and budget size, for example, below which it is not possible to conduct adequate pre-field work data searches, employ data-processing technology, or make use of site-dicsovery technology that might be appropriate. The use of ground-penetrating radar costs about $1000 per day at the present time and cannot be divided into smaller fractions in most cases. Synthetic-aperture radar flights cost about $3000 per hour and cannot be made in increments of 10 or 15 minutes to suit a small-scale project. If a project has a funded crew of two persons and a field time allowance of a week, it is unrealistic to expect that the crew will be able to employ a multi-stage sampling design. Many more examples could be given, but these should be sufficient to indicate that the small-size project, which probably exemplifies the great majority of survey projects in most parts of the country, cannot take advantage of many of the site discovery procedures available to the sort of large-scale projects discussed by Schiffer, Sullivan and Klinger (1979) and others. In such cases, the probability of sites being discovered is reduced.

Site Discovery Problems:

This discussion serves to indicate that the discovery of archaeological remains or sites is not a straightforward matter, and that failure to control for these factors casts a survey's results into

uncertainty. Cost-efficiency is not served by obtaining dubious and biased results through economies of budget alone, yet obviously the resources available to conduct archaeological surveys are limited, and the efficiency and productivity of surveys can be maximized only within the limits of available resources. It is therefore important to determine how these maximizations can be realistically achieved. Such a consideration must begin with a discussion of the nature of archaeological site or resource discovery.

THE DISCOVERY OF ARCHAEOLOGICAL REMAINS:

The result of archaeological survey is the discovery of archaeological remains. How is this end actually achieved? One way to answer this question is to examine the consequences of several site discovery procedures.

One form of discovery results from surveyor observation of artifacts or distinctive features and soils on the ground. This is, in fact, the most common form of site discovery. The most commonly found site evidence is the recognition of stone artifacts, broken pottery or similar debris, on the surface of the ground or in exposed soil. Although of low obtrusiveness, such remains may be highly visible and often are fairly abundant and clustered to the searcher who sufficiently overcomes accessibility and other problems.

Remote sensing relies on quite different lines of evidence to suggest the existence of archaeological remains. Aerial photography, for example, may indicate the remains of a buried structure because of crop marks or soil marks. A resistivity map may indicate the

presence of site features by recording distinctive patterns or anomalies in soil resistence. Radar may provide similar patterns from radar echo readings, and proton magnetometry, from anomalies in magnetometer readings on a grid. Soil chemistry measures, such as pH or phosphate, may also provide readings maps that indicate distinctive anomaly patterns.

Remote sensing devices are interesting in this context because they measure different kinds of phenomena than are measured when sites are discovered by pedestrian surveyors. They emphasize the point that different site discovery (or archaeological remains discovery) techniques measure different attributes of sites. Discovery techniques, in other words, are attribute-specific. Furthermore, it can be pointed out that no single technique is able to sense or recognize all site attributes. Since different kinds of sites possess different combinations of attributes, no one technique is adequate to reveal all kinds of sites. Even sites of the same kind may differ in the array of attributes actually detectable to a given technique.

This situation has implications for site discovery strategy. It suggests that the kinds of sites likely to be encountered in a given study, and the circumstances of their settings, need to be predicted so that techniques appropriate to the recognition to those specific attributes can be selected.

The further point can be made that site survey does not result in the observation of sites, but rather of attributes of sites. With rare and unimportant expections, archaeologists do not observe sites as whose during the process of discovery. Instead, they observe the occurrence of one or more attributes normally associated with sites,

and from those discoveries predict that a site exists. Confirmation of this hypothesis usually involves the discovery of more examples of the same attribute or more attributes in association. Some site attributes, for example soil marks or anomalous pH readings, may occur through non-cultural means. For this reason, the discovery of an apparent site attribute requires confirmation in the form of the recognition of further attributes -- what Schiffer, Sullivan and Klinger (1979) call "ground-truth verification." Their term, used in the context of verification of sites suggested by aerial remote sensing, actually can be applied to cases in which the initial discovery is made on the ground as well. For example, the discovery of a fire-cracked rock, or of an area of stained soil, or an ash pocket, or a piece of fractured chert, may reflect human activity or it may not. Conceivably an attribute found on the ground might be tested through "air-truth verification" -- confirmation through aerial photography or airborne radar, for example -- with just as much validity. Although this situation is unlikely to occur, it indicates that the confirmation of the existence of a site (or a concentration of archaeological remains) depends on the discovery of covariant site attributes rather than the recognition of a site as an entity in and of itself.

SURVEY STRATEGY AND THE DISCOVERY OF ARCHAEOLOGICAL REMAINS:

If the goal of survey is the discovery of an area's archaeological resources, a survey's strategy should be designed to maximize discovery. This in turn means that it should maximize the probabilities that a surveyor will actually observe the remains that may exist in an area, or what Dincauze (1980) calls "encounter probabilities".

Three kinds of information are needed in the development of an appropriate survey strategy: estimations of the kinds of resources likely to be encountered, estimations of the obscurity factors in a study area that are likely to affect observation of the attributes or resources, and estimations of the dispersion patterns and density of the remains or attributes. Given an estimation of the kinds of attributes present, it is possible to select techniques of discovery that are capable of sensing the attributes or remains. For example, the the attribute present in an area happens to be phosphate concentrations in otherwise undistinguishable soil, a visual search technique would be inappropriate but a soil chemistry sampling technique would be appropriate.

Given an estimation of obscurity factors, it is possible to design the application of techniques so as to reveal the chosen attributes. For example, if the most common attribute in an area was the presence of stone flakes, but the ground's surface was covered with grass, a visual search, normally capable of identifying flakes, would not be appropriate, but some sort of subsurface sampling technique, capable of revealing the existence of flakes in areas with obscured surfaces, would be appropriate.

Given estimates of the density and dispersion patterns of attributes in a study area, it is possible to select a sampling scheme for the application of a particular search technique that is appropriate to the situation. For example, if a given area is characterized by the occurrence of low-density flake scatters, a sampling scheme that involved the drilling of auger holes at intervals of 100 m. along transects would stand little chance of revealing a representative

sample of remains, whereas a search technique that involved the excavation of 50 X 50 cm. test pits at 10 m. intervals along a 10 m. grid of transects would stand a far better chance. However, if the area were characterized by the occurrence of small numbers of large, dense, rich midden deposits, a search pattern making use of auger borings drilled at 100 m. intervals would not only be appropriate, it would be preferable to a more internsive search because the more intensive procedures would cost more than was needed to achieve adequate discovery results.

One of the ironies of this situation is the need for more intensive search techniques for less intensive remains. It means that the areas with the least rich, least impressive archaeological resources actually require the most intensive surveys. This situation contradicts the inclinations of many archaeologists and non-archaeologists alike to put their greatest resources toward the study of the most impressive remains. In this matter it is essential to separate the task of discovery from the tasks of interpretation and mitigation, during which resources may well be used according to the richness of remains simply because of quantity.

In many survey strata, it is the case that there occurs one or a few fairly substantial concentrations of archaeological remains and a much larger number of less substantial remains. When such situations are expected, it is important that the search techniques chosen be those that are geared for the discovery of the least obvious expectable remains rather than the richest -- a so-called "minimum-site strategy." It is generally the case that a technique capable of revealing a small, low-density concentration will also reveal larger, richer, more dense concentrations of archaeological remains. The reverse is not true,

however. Obviously there must be some lower end to this effort. The minimal remain usually expected is the single artifact. There are important facts about the past that can be learned from the study of the distribution of individual artifacts in a landscape, but the chances of finding individual artifacts in adverse environments is not very good. It is not financially possible for a surveyor to strip an entire countryside in oder to have a high probability of finding whatever individual artifacts may occur. More important it is not necessary or desirable from a research standpoint. What is needed is a search technique capable of revealing such finds where it is applied, if they occur there, and a sampling strategy for the use of the search technique that will yield a representative sample of the area to be surveyed. Given adequate sampling tactics, 100% searches are not only not necessary, they are wasteful because the same information can be gained far more economically through appropriate sampling. Sampling tactics become inappropriate when they fail to find remains that occur where searching is done. However, it is possible to design appropriate search and sampling techniques. As Deagan has said of her subsurface surveys of St. Augustine and Fort Matanzas, so far no construction project has turned up sites in areas she surveyed that she failed to discover (Kathleen Deagan, personal communication, Tallahassee, 1980).

The key to effective site discovery, then, lies in the adoption and application of appropriate search or discovery procedures in appropriate sampling schemes. The main goal of the rest of this report is the review of discovery procedures. However, before starting that task, it will be useful to review the current status of archaeological survey procedures in general, including sampling.

II. CONTEMPORARY ARCHAEOLOGICAL SURVEYING

The purpose of this section is the review of contemporary topics, issues and questions concerning archaeological surveying. In order to avoid the repetition of available materials, we will only indicate what these subjects are rather than reiterating entire discussions. Some of this material has already been treated in the previous section, while ~~will~~ some other topics will be discussed in the subsequent one. Our goal is to give the reader some feeling for the state of the survey art at this time.

There are three main sources for material on this subject. One is the manual on archaeological procedures (e.g. Fladmark 1974; Hester, Heizer and Davis 1975; T. King 1977; Knudsen 1978). Such manuals tend to be very technique-specific without treating underlying methodological issues very thoroughly. A second source is the review article on survey philosophy (e.g. Plog, Plog and Wait 1978; Sciffer, Sullivan and Klinger 1979). These articles, few in number, tend to avoid discussions of specific techniques in favor of general issues, and also tend to be relevant primarily for large-scale projects. A third source is the report on a particular survey project, in which survey procedures are discussed and rationalized (e.g. Baker 1975; Carnes and Dickens 1979; Ferguson and Widmer 1976; Hayes 1964; Schiffer and House 1975; Whalen 1977). Such reports often combine both philosophical and technique-bound topics, but often are limited in scope to the particular setting of the survey. By considering all three kinds of sources, it is possible to arrive at a feeling for the current state of archaeological surveying. Readers who wish to pursue this topic more extensively than we have done here should refer to

these original sources.

Goals of Archaeological Survey:

The purposes for which archaeological surveys are done have expanded in recent years. Twenty years ago, there were found four general reasons for making archaeological surveys: student training, generally as an end in itself, the compilation of files of site records, the identification of sites for excavation, and the identification of sites threatened with destruction from proposed construction projects (Heizer 1958). The growth of interest in regional research problems, as reflected by Binford (1964), led to the development of surveys as means to gather data and test propositions on a regional scale as opposed to single-site excavations. The growth of cultural resource management added a new emphasis to the compilation of inventories of sites and the identification of sites eligible for nomination to the National Register of Historic Places. Environmental impact studies, which emerged during the 1970's, provided some differences in survey goals with the earlier salvage-oriented surveys. EIS surveys more typically considered the potential for adverse impact in a context of regional archaeology rather than as a series of site-specific dangers to be addressed piecemeal.

One of the aspects of the growth of archaeological survey is the emergence of a new field within archaeology, which might be called geographic archaeology. During the past 15 years or so, archaeologists have become increasingly sensitive to the human use of the environment in the past. Several lines of inquiry, such as the study of the distribution of settlements, the study of resource distribution, catchment analysis, and the analysis of the spatial distribution of archae-

ological remains, have come to rely on the site and the individual remain as units of analysis, rather than depending on the study of the distribution of remains within sites. Survey, therefore, becomes an appropriate research tool for this research.

Definition of Sites:

Earlier we discussed several ideas about the nature of archaeological sites and the meaning of the term "site." This sort of discussion would not have taken place ten years ago, because knowledge of the distribution of archaeological remains over space was poorer and research reasons had not yet emerged for reconsideration of the site as an analytic unit. The growth of surveys in areas characterized by low-density remains, however, brought traditional understandings into question and led to the development of such ideas as "non-sites" (D. Thomas 1975), and to emphasis on the recording of the occurrence of archaeological remains rather than archaeological sites (e.g. Goodyear 1975). Today the survey goal of the discovery of the distribution of archaeological remains over space is gaining increasing currency (e.g. Taylor and Smith 1978; Schiffer, Sullivan and Klinger 1979), and will probably characterize much survey reporting for some time to come. At the same time, however, the use of spatial patterning information concerning the distribution ofremains in regions will probably lead to a redefinition of the meaning of the term "site" within the next few years.

Definition of Archaeological Survey:

Changes in ideas concerning the meaning of the term "site" are reflected by changes in ideas concerning the nature of the archaeological

survey. Twenty years ago, an archaeological survey was considered to be the activity of searching for and recording archaeological sites. The more recent emphasis on the significance of non-sites and isolated remains has broadened the meaning of this definition (Heizer 1958). More importantly, archaeologists have become more conscious of the use of alternate techniques for the discovery of sites, and of the fact that the use of different techniques may yield different results (Plog, Plog and Wait 1978). Archaeologists have also become much more conscious of the use of sampling, of the incomplete nature of surveys, and of the importance of survey samples for the prediction of the archaeological record. From these concerns has come a somewhat changed definition of the archaeological survey: "...the application of a set of techniques for varying the discovery probabilities of archaeological materials in order to estimate parameters of the regional archaeological record (Schiffer, Sullivan and Klinger 1979:2).

Equipping the Archaeological Survey:

This topic is essentially technique-bound and is primarily found in discussions in techniques manuals of archaeological surveys. Such discussions have changed over time, however, and reflect changes in other aspects of archaeological surveying. Earlier manuals stressed little in the way of survey equipment: principally the use of the compass to locate sites, tape measure to measure sites, collection bags to hold surface artifacts and topographic maps for site location reference (e.g. Heizer 1958). Hester, Heizer and Graham (1975:20) list 20 items to be carried by a two-person survey crew. All are hand-carried items such as pencils, protractor, ruler, notebook, whisk brook, compass, camera, tape measure and exposure meter. Hole

and Heizer (1977) stress the advantages of using aerial photographs as well as topographic maps in the field to locate sites.

Only in the last 4-5 years has an emphasis arisen on the use of a larger array of equipment in archaeological survey. This new emphasis has developed primarily in the eastern U.S. where heavily forested landscape has forced surveyors to undertake subsurface testing on a systematic basis. Currently it is most common for survey crews to use either shovels or post-hole-diggers to test below the surface during surveys, and often the testing is accompanied by sifting with portable screens. Most users of the post-hole-drilling approach make use of motor-powered augers. Less common, but still of note, are the users of remote sensing instruments in survey: such instruments as proton magnetometers, resistivity meters, soil chemistry meters of various sorts, metal detectors and ground-penetrating radar, for example. The use of such instruments in site discovery has become noticible mainly during the past 3-4 years. The addition of such equipment has changed the logistics of surveying. Survey crews which must rely on such equipment have lost flexibility and maneuverability as they have gained in site discovery ability. In the process surveying has begun to lose some of its informality and generality. Just as excavation a generation or more ago began to draw an ever-growing number of technical specialties into its sphere, survey has begun to require technical expertise beyond the level afforded by survey crewmembers. Although it is not currently the case, there is an apparent trend toward the development of a new kind of survey team, composed of a series of technical specialists rather than a group of equally- trained general surveyors. Such a development would probably both increase the variety and power of things that could be

done through survey research, and add greatly to the cost of doing surveys.

Sampling:

Sampling is the aspect of surveying that has received the most attention and innovation in the past decade or so. Of most importance has been Mueller's study of various sampling techniques in survey (Mueller 1974) and several papers in his 1975 collection on sampling in all aspects of archaeology (Mueller 1975). More recent papers summarize current thinking about sampling during survey (e.g. S. Plog 1976, 1978; Plog, Plog and Wait 1978; Schiffer, Sullivan and Klinger 1979; D. Thomas 1978; Connolly and Baxter 1980).

During the 1970's archaeological surveyors were concerned with the development of appropriate probability sampling procedures for survey. This involved the selection of units of search by means of some form of random sampling. In a simple random sample selection, a study area would be divided into a number of equal-area units, and a number of the units would be chosen for examination. In a stratified random sample, the study area would be first stratified based on prior knowledge, perhaps according to topography, the distribution of plant and animal communities, or previously-determined patterns of site distribution. Each stratum would be subdivided into equal-area units and a number of search units would be chosen for study within each stratum by random means. Although the many efforts at probabilistic survey sampling offer a bewildering array of experiences, it is generally the case that such efforts aimed at the estimation of an area's total archaeological resources by means of projections from the samples gained in the selected search areas. Although this may seem self-

evident, there are a number of interesting dimensions to it.

One dimension concerns the assumption of examination. Most discussions of survey sampling assume explicitly or implicitly that the selection of a search area implies 100% examination of the search area, or that there are no significant impediments to site discovery. We discussed earlier that this assumption is often false. Another aspect of it concerns the totality of search within the search area. As Plog, Plog and Wait (1978:394) point out, survey intensity can vary significant independent of sampling strategy or obscurity factors. Just because an area has been chosen for study does not mean that it will be thoroughly surveyed. For example, Lovis, in his survey of sample quarter-sections of forest in northern Michigan, had his crews dig test pits along transects within the quarter-sections. As Nance (1979) points out, this is really only a sample of a series of points within the chosen quarter-sections, not of the quarter-sections as wholes as Lovis suggested (Lovis 1976). The same can (and usually does) occur with above-ground surveys. Not only are many site attributes hidden from view, but even when they are not such factors as the spacing of searchers affects the discovery probability for resources. The Forest Service in California has adopted a surveyor interval of 10 m. as a standard for "total" survey coverage of a tract. Under this standard, a series of search transects no more than 10 m. apart is established across a search area. Each transect is walked by a surveyor searching for surface archaeological remains. Since at least 75% of the ground's surface is not directly observed under this pattern in the best of circumstances, and the percentage often is nearly 100%, the term "total coverage" is clearly something of a misnomer (Joseph C. Winter, personal communication Eureka, 1978).

Another dimension concerns the nature and validation of sample estimates. Archaeological survey sampling invariably suffers from the lack of valid estimates of variance. In addition, sample estimates rarely are validated through re-sampling or other testing programs. Instead, archaeologists are generally content to rely upon the assumptior on which their statistical tools are based. Reasoning based on such assumptions becomes tautological (P. J. O'Brien, personal communication, Manhattan, KS, 1980; Schiffer, Sullivan and Klinger 1979:10).

Probabilistic sampling in survey has become institutionalized in contract programs because it offers the only statistically available means to estimate archaeological resources. However, many surveyors faced with the need to implement elegant sampling designs and also to estimate the archaeological resources found within an area have recognized that probabilistic survey sampling has serious limitations as well. Surveyors who make use of existing knowledge rather than random search area selection usually find a great many more sites than random samplers (e.g. Baxter 1979; Connolly 1979; House and Ballanger 1976). Random sampling in archaeology necessarily means that many, usually most, units have no archaeological remains in them. Random sampling is a poor way to discover rare or clustered ramains, particularly small ones, and may not be cost-effective (Schiffer, Sullivan and Klinger 1979:1-2). As a result, some researchers either abandon random sampling or supplement it with non-probabilistic surveying. Two approaches to non-probabilistic surveying can be noted: purposive surveys and opportunistic surveys. We refrain from calling them purposive or opportunistic sampling because they do not necessarily reflect systematic sampling designs.

A purposive survey refers to the examination of areas of predicted

site occurrence. An opportunistic survey refers to the examination of areas of soil accidentally exposed by such causes as gopher burrows, stream cuts or roadbeds. Purposive surveys are advocated by Schiffer, Sullivan and Klinger (1979) as a supplement to probabilistic surveys but actually they reflect an opportunity for probabilistic surveys. They reflect the use of existing information, which may be archaeological ethnographic, historical or environmental in nature, to stratify an area according to predictable site occurrences. As purposive surveys are typically discussed, the areas of high site predictability are tested by non-probabilistic means, such as by sinking test pits in areas where sites are expected. However, there is no inherent reason why such areas could not be sampled probabilistically as well (Ferguson and Widmer 1976).

The situation of opportunistic surveying is less elegant theoretically. Most surveyors use the opportunity to look over rodent burrows or other accidentally exposed patches of soil for evidence of artifacts. However, there is no inherent relationship between the exposures of such patches of soils and the distribution of archaeological remains, so such exposures cannot be depended upon to reveal archaeological remains in a representative way (Fox and Hester 1976; Thomas R. Hester, personal communication, San Antonio, 1980; P. J. O'Brien, personal communication, Manhattan, 1980; George Zeimens, personal communication, Laramie, 1980).

Recent commentators on survey sampling have been concerned with sample fraction and sample size. Sample fraction refers to the percentage of coverage, while sample size refers to the number of observations made (Plog, Plog and Wait 1978:395). While it is possible in some fields to make accurate predictions from very small sample

fractions, in general archaeologists lack the detailed knowledge needed to stratify a sampling universe accurately enough to permit the use of small fractions. Sample size varies inversely with unit size if sample fraction is constant. In general, an increase in sample size increases cost because logistical costs are raised, since it is cheaper to concentrate work in one area than to spread it over many widely-separated areas. Low sample size increases the risk of bias because of nonrepresentativeness. Schiffer, Sullivan and Klinger (1978:12) suggest that archaeologists avoid the use of sample sizes of less than 30 units if possible so as not to violate the contingency requirements of relevant nonparametric statistical tests.

As we previously noted, archaeologists generally cannot estimate variance in their predictions. This is because samples are based on units of land but the target population is not land. It is the archaeological resources distributed upon the land. Archaeological resources are not distributed randomly or uniformly, so there is no direct relationship between the percentage of land in a sample and the percentage of the archaeological population on that land in the land sample. Archaeologists cannot know ahead of time what the archaeological population size they sample is (Plog, Plog and Wait 1978:395-6). However, it may be possible to generate some estimates through simulation models based on thorough surveys. If such projections prove useful and reasonably accurate, estimates of variance may become practical (e.g. Pilgrim and Thor 1979).

Unit shape is a related topic of recent interest. Two survey units shapes are most commonly discussed: quadrats and transects. A quadrat is a square unit, while a transect is an elongated unit that resembles a line but in archaeology has a width up to 10% of its

length. The Plogs have been among the chief advocates of the transect as a survey unit (e.g. F. Plog 1974; S. Plog 1976). The choice of a unit shape is not simply a matter or aesthetics or logistics. Unit shape affects both site discovery probabilities and predictions. Transects have more edge per unit area than quadrats. Since sites cover two-dimensional spaces rather than occupy points, a unit edge can intersept a site perimeter at any point. The site may lie predominantly within or outside of the unit. The greater the edge, the more sites that may be encountered. Transects therefore may lead to more site discoveries per unit area than quadrats. Predictions based on these samples are correspondingly different. Although comparati data are rare, it is suggested that predictions based on transect samples tend to be biased in favor of abundance as compared to prediction based on quadrat samples. Such biases can be corrected with weighting factors. It should be noted that quadrats can produce biases at the edge, too: unit size varies inversely with "edge effect" bias, such that the smaller the unit, the greater the overrepresentation of sites due to the greater total edge involved. Although transects appear superior as discovery shapes, they have limitations as well. For example, transects are more likely than quadrats to cross-cut ecological boundaries, leading to confusion in site distribution correlates. Transects are potentially more likely to exhibit directional bias than quadrats, although this can be partially controlled through randomization of direction. Transects have higher logistical costs than quadrats of the same area since the sample size is larger in transects. For these reasons, different archaeologists remain in favor of each unit shape (Judge et al. 1975; Plog, Plog and Wait 1978; Schiffer,

Sullivan and Klinger 1979; Taylor and Smith 1978).

Cluster sampling has drawn considerable comment during the past several years. Mueller (1975:39) has claimed that the use of probability samples in survey is cluster sampling. Plog, Plog and Wait (1978:403-4) argue against this claim, saying that simple counts of site numbers per unit area do not constitute clusters in the statistical sense. The issue is significant because in general surveyors have not been using cluster sampling strategies. This fact would call to question the results of their predictions. If a study calls for the analysis of site contents within unit areas, then clustering would be manifested and the implications would change.

Ten years ago the battle over the need for sampling rogor was still being fought in archaeology. Today the battle is over, and most archaeologists, especially those involved with cultural resource management, accept the need for reasonable sampling strategies. Implicit in this acceptance is the premise that, over time, as knowledge grows, the need for probability sampling will become increasingly replaced by knowledgeable stratification, with probabilistic sampling taking place only within the strata. Currently, archaeologists are not developing procedures for achieving this transformation, although it takes place <u>de facto</u> in long-term projects as surveyors learn more about sites and distributions within a region. This area, we think, will occupy a growing importance in the next decade.

Another subject that we suspect will enjoy growing importance over the next ten years is the testing of sampling strategies in controlled, comparable settings. As Plog, Plog and Wait (1978:394-6) indicate, there are relatively few controlled studies available that test alternate methods. Archaeologists still know relatively little about

the differential consequences of using alternate sampling strategies. Knowledge about the consequences cannot be gained by reference to the assumptions on which the different methods rest.

Discovery Probabilities:

The emergence of alternate techniques for site discovery has led archaeologists to the realization that the application of different techniques changes the probabilities that a particular remain will be encountered, or discovered. Thus in the last few years the term "encounter probability" or "discovery probability" has been entering the vocabulary of archaeology (e.g. Dincauze 1980). Archaeologists are really not yet at a point at which such probabilities can be given realistic quantitative measures, although this may become possible within the next decade or so. It is possible, however, to express some probabilities in relativistic terms. For example, some archaeologists have become aware through empirical means that the use of a post hole test affords a lower probability for the discovery of a flake scatter than does the use of an excavated test pit with a 30 X 30 cm. surface area (Brooks and Scurry 1978; Claassen and Spears 1975; Hanson and Most 1978; Scott, McCarthy and Grady 1978). Still generally lacking are more detailed experimental results. For example, what is the difference between using auger borings and shovel tests whose aggregate volumes are equal? Also lacking are evaluations made with reference to different kinds of archaeological remains as well as with reference to different techniques.

Discovery Factors:

Discovery factors refer to such things as abundance, clustering,

obtusiveness, visibility and accessibility. We discussed these topics earlier, so we will not repeat our comments here. We would point out, however, that these concerns have arisen among archaeologists mainly during the past five years or so, as reflected by the fact that standard techniques manuals do not yet discuss them. They seem to have emerged as a direct consequence of the growth of cultural resource management. The expansion of surveys in remote areas, for the purpose of environmental impact assessment, led archaeologists to have to deal with wider ranges of materials than ever before, to have to conduct surveys in more demanding environments than ever before, and to be responsible for ephemeral data more than ever before. Most archaeologists did not have to confront the problems posed by factors that inhibit site discovery until then. As the proceedings of the Society for American Archaeology's annual conferences show, site discovery factors had emerged as significant symposium topics only by 1978, and have become increasingly common subjects since then.

Discovery Techniques:

The use of innovative discovery techniques to overcome site-obscuring factors has grown along with concern for those factors, mainly during the second half of the 1970's. These techniques, too, tend not to be mentioned in standard techniques manuals as elements of archaeological survey. Most techniques have been in use among archaeologists for some time, usually as means for studying the internal structure of known sites. Subsequently they have become applied to site discovery problems as well. Core drilling, for example, was popularized early as a technique for exploring sites, and has become common as a discovery technique only in the last five years (e.g. Reed, Bennett and Porter

1968). A major exception is aerial photography, which has been used as an important site discovery technique in some areas for a half century (e.g. Reeves 1936; Solecki 1957).

Faced with the difficulty of finding sites reliably in many parts of the nation, as well as with the rising costs of the use of large labor crews, a growing number of archaeologists have been exploring alternate discovery techniques. Currently most of the available literature is devoted to descriptions of specific techniques and discussions of their applications. Well-controlled, quantified comparative experiments are still quite rare, but papers of this sort are starting to emerge as the need for comparative information grows (e.g. Ives and Evans 1980).

Site Location:

The determination of the location of discovered archaeological remains is an essentially technical problem that has become of more concern with the growth of environmental impact studies in the 1970's. It is a topic treated in techniques manuals, such as Hole and Heizer (1977), and Hester, Heizer and Graham (1975). Since then there has been a growth in the use of the Universal Transverse Mercator Grid as well as political boundaries or latitude and longitude for site location. The use of detailed aerial photos to complement topographic maps has also increased markedly. There is still comparatively little use of technological innovations such as directional locator beams. In that the bulk of remains now being found in many areas are small and occur in wilderness environments, we suspect that the application of technology to site location determination will grow markedly during

the next decade.

Site Recording:

The proper recording of sites has been a topic of more or less continual interest among surveyors for decades. Recording procedures have changed markedly in the past 5-10 years, however, due to the needs of environmental impact studies.

The maintenance of files of site records has been done for many years by research institutions. Before World War II such records were characterized by enormous diversity among institutions, although most variants provided the same basic sets of information: some form of site designation, data on location, land owndership, some physical descriptions of the site and its immediate surroundings, and some brief notes about the kind of remains associated with it and its cultural affinities. Such records were generally restricted to prehistoric and ethnographic sites.

In the period after World War II the nature of site records did not change but the form often did. Many institutions adopted a variant of the form developed by the Smithsonian Institution and used widely in its river basins surveys (e.g. Heizer 1958). Hester, Heizer and Graham (1975) present a typical lengthy discussion of the meaning of each of 36 categories of information required by the form in promotion of standardized information collecting.

Not until the growth of cultural resource management in the 1970's did the limitations of the Smithsonian form first become widely apparent and resource managers and researchers began to try to use the corpi of recorded sites to develop policies and conduct research. Part of the problem had to do with the fact that in many cases records were

incomplete, requiring a repetition of much work. Of more importance, however, were the facts that much information proved to be too vague and limited for successful use toward any practical end, and that information was often not collected in a sufficiently comparable form that entries meant the same thing from one case to the next. As a result, rapid development of new recording forms occurred. In some cases, newer and more highly detailed forms became institutionalized. The Forest Service in California, for example, uses a form for site evaluation that has a minimum of eight pages and includes automatically such data as the bibliographic references checked by the surveyor before and after survey and contact prints of the site and its artifacts or features. The museum at Arizona State University has adopted a 12-page site recording form accompanied by a 20-page manual of instructions to surveyors on filling out the form (Plog, Plog and Wait 1978; Fred Plog, personal communication, Tempe, 1980). Many surveyors also regard the form of a site recording instrument as flexible, as something that should be developed and adapted in the field to best fit the circumstances of a particular research project (e.g. Schiffer, Sullivan and Klinger 1979). This attitude makes site recording forms more like interview schedules used by sociologists. For archaeological survey, it promotes data recovery and internal comparability within a project, although it may reduce comparability of the records made during different projects.

The use of the computer also affects site recording. Some institutions have computerized their site files to permit readier retrieval and data manipulation. This has led to internal standardizations of information. The profession as a whole is still a long way from

agreement on the nature of site data bank forms and language. This topic may be expected to be a major area of discussion in the coming decade. The use of in-field terminals for site record entries is still generally impractical due to the mobile nature of surveying, although the development of mini-computers at low prices will probably change that situation. Schiffer, Sullivan and Klinger (1979:14) quote Klinger's use of optical scanner forms in the field for site recording. This technique, which eliminates the need for key-punching, may greatly accellerate the use of site record data banks.

Record data banks themselves are evolving rapidly as the use of site record information for management purposes accellerates. Until recently, site record files were generally housed at research institutions such as museums and universities. Access to the data was generall tightly restricted to protect sites from vandalism, and the data were generally used almost exclusively for research purposes. In the 1970's other organizations began to become involved with both the accumulation of site records files and the use of the files for management purposes. Chief among them were state and federal land-administering agencies, who compiled inventory files in accordance with P.L. 89-665 and E.O. 11-593. The support of surveys through environmental impact studies under P.L. 91-190 led to the generation of new bodies of records and interpretive reports relating to known sites. The development of the program of state historic preservation officers with responsibilities for site significance evaluation led to the participation of another branch of government in the data bank development process. The growth of contract archaeology required that contract bidders and awardees have access to data banks in order to conduct their research.

All these developments led, in the last decade, to a rapid expansion of the size of site record files, the numbers of organizations and individuals participating in the formation, management and use of the data banks, and the purposes to which the data were being put. To a growing degree, research archaeologists are losing the autonomous control over these data banks that they once enjoyed. At the same time, many states are evolving toward the development of centralized site record data banks, automated to an unprecedented degree. The development and support of such data banks is generally beyond the the abilities of most archaeological research laboratories and contractors to provide, so much of this development is occurring within government agencies, and generally for administrative purposes. However, the research potential for such data banks is vast, and the tapping of it is to be anticipated with great excitement. At the same time, the proliferation of site records outside the research institutions and the expansion of access to the data by many kinds of interested parties, promises to pose security problems equal to the advantages gained.

Surface Collection:

The conduct of surface collection and the propriety of making surface collections have come under vigorous discussion during the 1970's. The collection of representative or diagnostic artifacts during survey is as old a practice as survey itself. Traditionally this practice involved the making of intuitive judgments at the site at so what to collect -- a so-called "grab sample." Many archaeologists did not become concerned about the representativeness of surface collections and the implications of grab-sampling as a form

of sampling until fairly recently (see Ragir 1967).

The uses to which surface collections were put were traditionally very limited. However, ten years ago Redman and Watson (1970) argued that well-collected surface collections could be used to predict the subsurface structures of sites. Binford (1964) had earlier argued for the systematic surface collection of sites so as to characterize their structures without excavation. In spite of the fact that relativel sophisticated sampling designs have been evolved for survey, the "grab sample" still predominates for surface collection.

Within the decade past some archaeologists and agencies have argued against the collection of surface remains, mainly on grounds that their removal helped destroy the resource to be preserved, but also on grounds that surface artifacts often were of dubious provenience. In that this position became policy in certain agencies, it affected the kind of research that could be done in a survey context. Other archaeologists and agencies have resisted this position, arguing that failure to collect did not protect the resource, and that valid research could be done with surface data (see Butler 1979, for example). The practice of surface collection remains widespread at this time and the non-collection movement does not appear to be gaining strength.

Given the continuation of surface collection, archaeologists have become concerned with various schemes for making effective surface collections. A universal concern is the preservation of provenience information within the site. Plog, Plog and Wait (1978:408-9) provide a discussion of several alternate collection strategies.

Site Testing:

The testing of discovered sites is becoming an increasingly standard survey practice in several parts of the country. We distinguish be- testing as a discovery technique and testing to study a site's internal structure. Post-discovery testing generally has two main goals: to test or confirm ideas about a site's nature based on observable surface attributes, and to collect types of data (such as faunal and floral remains, stratigraphic information and information about features) not present at the surface (e.g. Schiffer and Gumerman 1977:190). The stimulus for post-discovery testing stems mainly from the need to assess a site's significance relative to possible environmental impact mitigation and to possible National Register nomination. Site attributes visible at the surface may be either insufficient for the task or of questionable status, so that further data collection in a better-controlled setting may be required.

Archaeologists have not yet begun to be seriously concerned about the problems of sampling attendant to such post-discovery testing, or to develop testing strategies other than existing ones associated with normal excavation, to deal with these needs. The emergence of post-discovery testing as an aspect of survey indicates the growing maturity as a research activity rather than as a natural history activity. It indicates a blurring of the once-fairly distinct difference between survey and excavation. It also suggests the evolution of archaeology's field procedures toward the collection of needed information, regardless of the context, rather than as a part of a routine activity such as survey or excavation.

Multistage Survey:

The growing maturity and complexity of archaeological survey has promoted thought about the efficient organization of work. For survey, this line of thought has followed the multi-stage research model discussed by Redman (1973) as well as others in regard to regional research leading to excavation. Plog, Plog and Wait (1978) and Schiffer, Sullivan and Klinger (1979) discuss aspects of multistage survey organization, perhaps reflecting suggestions in the Airlie House Report (McGimsey and Davis 1977) for research organization. There are three critical elements in the multistage scheme that are of concern here: background data, feedback and retesting.

While archaeological manuals have always promoted the study of existing information prior to field work, the traditionally casual nature of survey did not stimulate extensive pre-survey research. The concern of funding agencies for cost-effectiveness has helped to formalize survey and has helped in the process to promote taking advantage of existing knowledge in the design and execution of further field work. The scope of pre-survey research may range from existing site record, survey and excavation data to ethnography, ethnohistory, history, sociology, environmental studies, interviews, and relevant methodological and theoretical literature. Ideally, the use of existing knowledge allows the surveyor to design the most appropriate field strategies, to avoid wasting time and money, to avoid figuratively re-inventing the wheel at regular intervals.

The multi-stage design also anticipates that knowledge will be gained during the course of field work about the particular environment and the particular archaeological resources at hand. It is anticipated

that advantage may be taken of this gain in knowledge to modify the research design, making it even more effective, and to make original plans for later stages of research that could not have been made on an informed basis prior to field work. The multi-stage scheme thus advocates not just an explicit research design for survey, but one that is flexible, and which is developed in stages to take advantage of ongoing gains in information. Earlier than about 4-5 years ago there was little thought in the literature about multiple stages to surveys, so the emergence of an evolutionary model represents a radical departure. However, archaeologists have not yet begun to debate the nature of such designs, so we expect it to be an important topic of discussion during the coming decade.

Finally, a multi-stage design allows, or can allow, for the testing of models developed from data collected in the early stages of field work. The need for multi-stage testing was anticipated by Redman (1973) among others. In fact, however, archaeologists still do remarkably little multi-stage sampling to test their own models within the confines of individual research projects. As noted earlier, many archaeologists appear content to accept the premises of the original sampling schemes rather than to independently test the models resulting from the sampling. However, a multi-stage survey design would allow for testing, there are cases of it being done (e.g. Theodoratus et al. 1979), and it should become more common in the future.

Worker Variability:

The variability in work quality that can occur among crews and individuals on survey projects was discussed in the previous section.

As we noted, it is a problem that is only now coming into discussion (e.g. Plog, Plog and Wait 1978, who present some experimental analyses). This subject may be one in which survey research leads excavation research in analyzing the problem and devising controls. Clearly, the rise of concern over comparative worker quality is a direct outgrowth of cultural resource management and the need for thorough and comparable survey results.

Interviews with Local Collectors:

The relationship between research archaeologists and relic or artifact collectors has never been very comfortable. The demands of cultural resource management, however, have led many archaeologists to seek the help of relic collectors (by which we do not refer to avocational or amateur archaeologists) in site discovery and evaluation. This willingness to work directly with individuals traditionally defined as vandals indicates a new and interesting development in survey. Some writers have begun to analyze the variability in collectors' knowledge and behavior in order to use these sources for site recording and discovery (see, for example, Gero and Root in McManamon and Ives 1980).

Cost Effectiveness:

A growing concern in survey literature concerns the finances of field research and the management concept of cost effectiveness (e.g. Butler 1978; Cunningham 1979; Walka 1979, for example). Interest in business concepts in general may be traced directly to the rapid growth of contract archaeology, prior to which few archaeologists regularly handled enough funds to make an interest in management a

serious concern. The specific concern for cost effectiveness may be traced to the concerns of the agencies funding contract archaeology. Most contracted archaeology projects are surveys, and survey, like other aspects of archaeology, has traditionally been labor-intensive. Much research has traditionally been conducted in a cash-poor framework, for example through the use of student trainees as part of coursework, or with volunteers. Furthermore, few archaeologists or government officials appreciated 15-20 years ago how very little of the nation had been well surveyed or how much remains awaited discovery. The realization of the magnitude of the survey situation dawned upon funding agencies during the 1970's as proposals for environmental impact studies were reviewed. Of course, the addition of any new new sphere of responsibility to a mission-oriented, land-administering agency meets with resistence, and archaeology is no exception. Hence the enthusiasm for work-scope concessions and management concepts of cost containment on the parts of some administrators.

Many archaeologists, for their part, have not been seriously concerned until recently with cost efficiency, since in more strictly scientific circles financial support levels control the quantity of work more than the quality and management needs can be more effectively subordinated to research needs within budget limits. In addition, the often cash-free nature of much early survey work allowed issues of business economics to be avoided altogether.

The emergence of contract archaeology in the 1970's however, has moved survey to a fully cash-supported status, so it has changed the measures by which evaluations are made. Schiffer, Sullivan and Klinger (1979:2) note that some archaeologists are now beginning to keep work logs and other quantitative means to estimate the actual

costs and productivity of alternate procedures. Only on the basis of such information, when pooled, can cost effectiveness of survey designs begin to be determined in an empirical fashion. This topic should be an important one for discussion during the next 5-10 years.

Comments:

This brief review indicates that the state of archaeological survey has changed radically in the last decade, perhaps more so than in the prior century of archaeological survey. The transformation can be attributed almost entirely to the development of government-mandated cultural resource management, which brought large amounts of money to survey for the first time, created new needs for survey data, added new voices to survey evaluation, caused survey to be done in many areas hitherto largely ignored, forced archaeologists to deal with classes of data previously largely ignored, mandated formality where informality had prevailed, and imposed standards where few had previously existed. That the transformation is recent is shown by the fact that it is scarcely reflected in current manuals of field techniques, which give little place to survey and treat it as an essentially technical process. The management and research aspects of survey are treated little or not at all.

In the last decade, however, and especially in the last five years, survey has changed from being a minor archaeological field activity to being the most frequently performed field activity. Archaeologists have had to confront a host of methodological and theoretical issues and pragmatic problems as well, that they were able to ignore or avoid earlier. The present year sees archaeologists in the midst of trying to deal with these issues; most are far from settled.

The future direction of survey will be most interesting to follow. From the previous discussion, it might be assumed that survey will be subjected to revolution through the application of new technology, information management, business management and research design. However, these innovations tend to be applicable at comparatively high cost, and they tend to effect improvements and cost containments only when applied to large-scale, high-budgeted projects that would otherwise be subject to higher costs and greater inefficiencies through the use of more antiquated methods. However, most survey projects are still small-scale and low-budgeted. It would appear under the current status of things that it will not be economically feasible to apply many efficiencies on a small-scale, piecemeal basis. The pressures for continued refinement of survey, then, can be expected to come from client demands for more useful, more complete, better-quality data. In that case, we can expect to see the scope of activities conducted under the aegis of survey to expand, particularly in the post-discovery stage as regards evaluations of significance, and the pre-discovery stage as regards the adequacy of data recovery.

III. SITE DISCOVERY TECHNIQUES

Ultimately, the value of an archaeological survey depends on its ability to determine the archaeological resources of the study area, which depends in turn upon the means used to discover the resources. In this section we review a number of techniques either currently used or just appearing for site discovery or the discovery of archaeological remains.

The discussion is concerned with several points. The application of most techniques is described in detail elsewhere so it is generally avoided except where we feel clarity demands it. We are more concerned with the application of the technique to particular kinds of survey situations. We have taken the position that there are no ideal or universal site discovery techniques, but that each has certain abilities and limitations. We are concerned to identify the strengths and limitations of each technique as well as possible, to specify the circumstances under which it may or may not be effective, and the kinds of data that it may or may not be sensitive to. We will also present where suitable some experiences of researchers with the technique. When available, we will present cost and productivity data, although we note that local circumstances make such figures subject to large degrees of variation.

It was hoped that it would have been possible to compile more comparative quantified data on the performance of various techniques. Indeed, it is possible to offer comparative figures for some techniques based on the many reports our colleagues have so generously provided. However, we have hesitated to do so because we feel that the individual circumstances surrounding most such projects introduce large numbers

of uncontrolled variables into the subject, and make statistical comparisons open to question. It is possible, however, to begin to compile some descriptive statistics on the costs and performances of some of the techniques. The compilation of more such figures will begin to permit surveyors to make real choices among alternate equivalent and non-equivalent discovery techniques.

The form of the discussion will involve the consideration of each technique individually according to the criteria just indicated. At the end of the discussions, some comparative comments will be offered. The techniques to be discussed can be divided into two major groups, apart from traditional pedestrian survey: subsurface mechanical examination and remote sensing. Mechanical examination includes all procedures that involve the excavation of soil, by hand or by machine, to supplement visual examination. Remote sensing offers alternatives to visual examination, ranging from aerial and satellite radar and photographs to soil chemistry, electronic and electromagnetic sensing and magnetic measurement. This classification is not entirely exclusive; soil must be extracted to conduct soil chemical tests, for example, even though the object of extraction is not the visual examination of the soil. The system is adequate for the task at hand, however.

PEDESTRIAN SURVEY

Pedestrian survey refers to the procedure of examining the surface of a tract of land while walking across it in order to identify any site attributes or archaeological remains that may be encountered. It is the traditional technique of site discovery in archaeology. It is so traditional that a specific name for the technique, distinguishing

it from other techniques, was not even coined until the late 1970's (see Schiffer, Sullivan and Klinger 1979, for example, or Taylor and Smith 1978). This is because other site discovery techniques have only begun to become formalized as alternatives to pedestrian survey within the past few years. Previously, pedestrian survey was simply known as "site survey" (e.g. Hester, Heizer and Graham 1975; Heizer 1958; Hole and Heizer 1977; Knudsen 1978), or inelegant circumlocutions such as "walk-over survey" were employed (e.g. Chartkoff and Donahue 1980).

Pedestrian survey relies on visual examination to detect archaeological remains. It is done under the assumption that evidence for the existence of sites is present at the surface of the ground and is detectable through visual examination. Many sites fit this description, enough so that for many years archaeologists were able to rely on pedestrian survey as the only significant site discovery procedure. It was only on the need to discover sites in areas where visual examination was not possible directly that alternatives to pedestrian survey began to be developed.

Discussions of survey methods such as those in the standard manuals noted above had not been very explicit as to how pedestrian survey is actually done. It has been generally assumed that the execution of the technique is intuitively obvious. Instead, discussions of survey techniques have dwelt on other topics: how to read maps, how to locate discovered sites, how to select areas for search, how to fill out site record forms or how to make surface collections, for example. The implicit assumption has been that a site's existence is defined by the occurrence of surface artifacts, and that if a surveyor can recognize artifacts, there are no other discovery problems

of concern. Of course, at least two problems affect this inference: the fact that many visible site attributes cannot be observed in particular settings because of obscuring factors, and the fact that there are other site attributes than visible ones which can reveal the existence of a site or cluster of archaeological remains.

Nevertheless, pedestrian survey remains the single most important discovery technique in archaeological survey, even though it is becoming increasingly apparent that as a single technique it is inadequate in many situations. Its persistence remains strong for several reasons. A trained surveyor actually makes many kinds of observations in addition to the search for surface artifacts. Observations of topography, vegetation, soil patterns and significant geomorphological features, for example, can figure into site prediction and recognition in ways too complex and subtle to be easily described in discussions of survey methods (see Dincauze 1980; Barber 1980, for example). Thus pedestrian survey fits well into the multi-stage survey design (as in Schiffer, Sullivan and Klinger 1979:18, for example). It also has a high enough success rate that it cannot be discarded readily, especially when applied in non-probabilistic strategies. Regardless of the adequacy of the sample, in many (though hardly in all) parts of the country it is possible to discover many archaeological remains through visual examination. The problem is that pedestrian survey is a very unreliable way to judge the absence of archaeological remains.

Pedestrian survey is also cost-efficient for small-scale projects. Unlike the application of many forms of sophisticated technology, there is no effective lower limit to the cost of applying surveyors, and their multi-functional abilities make their use fiscally prudent on

low-budget projects where economies of specialization cannot be realized. In addition, pedestrian survey provides useful redundancy with other discovery techniques. A soil chemistry surveyor can also look for surface artifacts to confirm or reject any patterns apparent in the chemistry survey data. Pedestrian survey allows for flexibility in research design. A pedestrian surveyor, for example, can supplement a stratified random sample with purposive examinations of areas lying outside the chosen sample but which have high probabilities of site occurrences.

Now that other discovery techniques have been developed it can be appreciated that pedestrian survey is sensitive to only certain kinds of attributes or archaeological remains that may occur in an area. The most commonly mentioned attribute is the surface artifact, most typically a stone flake or tool. Along coasts and large river valleys crushed shell may be observed. Distinctive soils tend to be observable primarily in areas of dense settlement with sparse surface vegetation. Fire-cracked rock is frequently reported in many parts of the country, although the occurrence of cracked rock from non-cultural means makes it an indefinite site predictor. Visual examination may also reveal features of high obtrusiveness, such as standing chimneys, earth constructions and some plant distribution patterns.

Pedestrian survey is also insensitive to many remains. Apart from the fact that surface vegetation can obscure otherwise-visible remains, some remains are not directly visible even on exposed surfaces. Soil chemistry anomalies and the kinds of anomalies recorded by remote sensing devices tend not to be visible, for example. Many plant growth patterns cannot be seen on the ground due to scale, or perspective Buried remains of course cannot be observed visually from the surface.

Certain features cannot be perceived from the surface because the observer is not located at an appropriate distance, even though the features may be quite visible from other vantage points. The discovery of desert intaglios through aerial observation is a case in point. We did one survey in the coast ranges of Northern California in which, at one point, we were standing on a cliff overlooking a small river valley, watching some students walk across a terrace about 30 m. below. The students were walking through the depressions of more than 40 pit houses, but the depressions were so shallow and the ground cover so uniform that the students were unable to perceive the contours of the pit houses. From our more remote vantage point, however, we could tell when a student walked down into a slight depression and out again (Chartkoff and Childress 1966). These examples reflect a problem that might be called "focal length." As with a camera lens, set for a particular distance, only some phenomena are in focus; if the observer changes the relationship between himself or herself and the ground, different archaeological phenomena come into focus or go out of focus. From an elevation of 100 ft. a stone flake may not be in focus but a large crop pattern may be clearly visible. On the ground, the flake may be visible but the crop pattern may be out of focus. Each attribute is capable of being discovered visually, but only within the appropriate focal length.

The expense of pedestrian survey lies almost entirely in labor cost, as the equipment normally involved (compass, maps, bags, tape measure and other, similar gear suggested by Hester, Heizer and Graham 1975) is simple and inexpensive. Labor costs are extremely variable because of possible variations in the intensity with which pedestrian survey may be done. One private consulting firm recently told us that its

average cost per acre for pedestrian survey ranged from $9 to $12 but might go several times higher depending on the required intensity of the survey (James Fitting, personal communication, San Diego, 1980). Survey intensity can be increased by reducing the distance between transects walked by surveyors across a tract. The Forest Service in California currently calls for a maximum distance of 10 m. between transects (Joseph C. Winter, personal communication, Eureka, 1979). In a desert-area survey on Fort Bliss, however, a transect interval of 33 m. is being used (Glenn DeGarmo, personal communication, El Paso, 1980). A performance estimate can be generated by calculating transect length, transect interval and average time in motion over a fixed distance. For example, in our own survey of the proposed Paskenta-Newville Reservoir, in the western parts of Glenn and Tehama Counties, California, we surveyed about 80 sections of valley floor that had been stripped to the dirt of vegetation by grazing sheep. The study of the surface by surveyors who walked transects at 20 ft. intervals at an average rate of 2 mph. gave us a study rate of about 132 person-hours of labor per section (square mile) (Chartkoff and Childress 1966).

This rate is deceptive, however, because it is also affected by terrain and ground cover. When we surveyed a 120-section tract of the Klamath Mountains in northwest California, the surface in most areas was covered by almost impenetrable brush or forest duff. In order to achieve the same quality of visual examination in this study that we had achieved at Paskenta-Newville, we would have had to have undertaken massive brush clearance and duff removal. We did so in a sampling program, from which we can project a work average adjusted

to a square mile area. By our figures, it would have taken roughly 35,000 person-hours of labor per square mile to have achieved the same degree of visual examination in this study (the GO Road) as we achieved at Paskenta-Newville (Theodoratus et al. 1979).

To offer a contrast in another direction, one of us participated in a survey of a proposed desert park in the Antelope Valley area of southern California in 1962. In that study, the survey of a square mile was done along transects spaced an average distance of 200 ft. apart. Surveyors walked at an average speed of 3 mph. The work needed to cover each square mile was nine person-hours.

These examples indicate something of the upper and lower limits of survey intensity apart from simply increasing or decreasing the distance between transects. However, intensity can be varied in other ways as well. For example, Bickel (1978), working in Redwood National Park, has found that pedestrian survey productivity in terms of site discovery increases with re-visits to areas previously surveyed. A combination of factors appears to cause this. One is simply a time factor. The more time an observer spends in one place, the greater the liklihood that an obscure but visible archaeological remain will be observed. Another factor concerns natural variation. Between two visits such things as rain, wind, falling leaves or animal activity may change the observation conditions so that an archaeoloigcal remain that was obscured during the first visit becomes exposed for subsequent visits. A third factor concerns the light. The opportunitie to observe a phenomenon, all else being equal, change during the day as light conditions change. A fourth factor concerns crew behavior. A crew may be too tired in the late afternoon to keep up the level of observation they maintain while they are fresh, earlier in the day.

Archaeologists have not yet developed wholly adequate estimates of survey intensity, although some beginnings have been made in that direction. The Institute of Archaeology and Anthropology at the University of South Carolina, for example, has developed a scale to characterize ground cover density as it affects surface observability (Albert Goodyear, personal communication, Columbia, 1980), and use the scale to make estimates for designing pedestrian survey strategies.

Of course it must be pointed out that there are many situations in which pedestrian survey is a very effective site discovery procedure, often the single most effective procedure. For instance, the University of Michigan has been conducting surveys in the River Raisin drainage for several years, and in that part of southeast Michigan about 88% of the land surface is exposed regularly by plowing. Freshly plowed land offers good conditions for artifact observation, and when recently plowed land is washed by rain, the observation conditions are improved even more. Where such conditions exist or can be created, no other available technique is as productive as pedestrian survey for site discovery (Christopher Peebles, personal communication, Ann Arbor, 1980). This note makes another significant observation about the quality of pedestrian survey which deserves emphasis: even under supposedly "ideal" conditions of surface exposure, such factors as the time since the last rain and recent dust conditions greatly affect the probability that any given archaeological remain can be discovered. Where pedestrian survey can be done, it is still the most useful single site discovery technique available to the surveyor. It cannot be used in many situations, however, and it is currently being used in many cases in which it is inappropriate. Furthermore, even where it can be used, its reliability varies enormously. Sampling design alone

cannot equalize the variation. We suggest, therefore, that pedestrian survey not be regarded as the "standard" site discovery technique but rather as the generally most important technique out of many available for archaeology. It is a technique that does have definite and definable limitations. Because of these limitations, the use of other techniques must be considered as they are appropriate.

MECHANICAL SUBSURFACE PROBE TECHNIQUES

Among alternatives to pedestrian survey are a number of techniques that use mechanical means (either manual or power) to expose soil beneath the ground's surface. These techniques attempt to overcome factors that limit the observability of the ground's surface by exposing fresh soil for visual examination. Some work merely to strip a fresh soil surface and might be considered a preparatory stage for pedestrian survey. In most cases, however, these surface preparation techniques either must be used as point samples (e.g. Nance 1979) or else they also result in the bringing up of subsurface soil that would not otherwise have been seen, in which case they potentially present kinds of information not available to normal pedestrian examination. Thus they deserve to be treated separately from normal pedestrian survey. Other techniques are forms of excavation, which separate their observation circumstances altogether from that of pedestrian survey. The various techniques are similar, however, in that they rely essentially on visual examination for the recognition of site attributes, so they are generally sensitive principally to those attributes that are visually detectable.

We have defined a series of mechanical subsurface probes, and have tried as well as is practical to use terms already in use for the various techniques. This has not always been possible. In some cases, the same

term has been used by different researchers for different procedures, so we have had to choose one of the usages to adopt. In other cases, different workers have given different names to the same procedure, again leading to a choice of one term and an abandonment of another. In still other cases, a procedure has not been given a satisfactory name, or perhaps any name at all, so we have had to devise what we hope is a satisfactory one. This confusion is to be expected in a situation of rapid research development. We hope readers understand that we are simply trying to bring some order to a currently somewhat disorganized situation, and that we are not trying to impose a formal and permanent taxonomy on site discovery procedures. The following organization and set of terms should therefore be taken as a device of convenience only.

HOLE DRILLING TECHNIQUES

Several subsurface probing techniques function to dig or drill holes into the ground. While we shall consider them individually, a few general comments will be given for introduction.

The purpose of drilling a hole into the ground in archaeological survey is to expose a series of soil samples for visual examination. There are both power and manual machines to do this. Manual tools are cheaper to buy and operate than power tools, easier to transport cross-country, and generally take smaller samples. Even the power tools do not take large samples. The surface area of a 6 in. hole, for example, is somewhat less than 1/5 of a square foot. In general drilled holes may be made much more rapidly than excavated test holes, so sample size per unit area may be balanced against sample fraction per hole. There are discovery consequences for choosing to make this

tradeoff, and we will discuss them later. We will only indicate here at this time that there can be circumstances in which drilling, as opposed to digging, can be cost-effective, and other situations in which it is not.

The digging or drilling of holes has another advantage of note: the depth to which it can be done. The sort of digging by shovel that can be done as a sampling technique during survey does not allow very great depths to be reached -- rarely more than 20-30 cm. Hole drilling, even with hand tools, can normally be done to twice or three times that depth or more, and some power drills can be used to great depth. This fact is significant if remains-obscuring conditions cover sites to more than 20 or 30 cm. thickness. In such a case, the use of a shovel technique for discovery (we exclude the testing of already-discovered sites here) would be ineffective, while hole-drilling would be functional.

The soil pulled up by a hole excavation (it may also be called backdirt, spoil, fill, residue or <u>deblais</u>) is examined visually by some workers, and is sifted for examination of the contents in addition to visual inspection by others. The activity of sifting adds time to the processing of the sample but it seems to be widely found that the recovery of artifacts from hole backdirt is markedly improved when sifting is done.

We find four basic types of hole-drilling apparatus and techniques in use. They include: manual diggers of several types that each bring up piles of dirt; hand-operated soil core extractors; power operated augers; and truck-mounted well drills.

Manual Hole Diggers:

Manual hole diggers are hand-operated tools that excavate narrow, cylindrical holes in the soil. Three basic types of diggers are generally available: clam-shells, drills and plug removers. Depending on the type and the strength of the operator, the diggers can be used to depths up to about 4 ft. Drills may be as small as 2 in. in diameter, while clamshell diggers make holes about 6 in. in diameter. Most types are available for less than $20 per unit. Their use is usually very strenuous and, while a hole can be made faster than a pit can be carefully dug, these hand diggers do not work as quickly as power tools. However, the equipment is lightweight and portable, so it is more suitable for cross-country use than is power equipment.

Clamshell diggers are made of two facing half-shell scoops, joined by side pivot-rivets and fitted with long handles. Typically a user drives the tool into the ground with the scoops held open, and then closes the scoops together by spreading the handles. This operation cuts a plug of dirt free. The dirt may then be lifted out of the ground with the tool and the operation can be repeated until the desired depth is reached. Drills are made like drilling bits, with central axles around which a flange spirals from the tip to the mid-shaft. The drill is pushed into the ground and is turned in one direction, usually clockwise (depending on the direction of rotation of the flange). This action drives the bit into the ground and the turning spiral lifts up the loose dirt and dumps it around the hole. Plug cutters are like core drills in that they have a hollow center, but are not meant to extract intact cores. A plug cutter

is a hollow cylinder, typically about 6-8 in. long and 2-3 in. in diameter, mounted at the end of a long handle. It is pushed or twisted into the ground and then pulled out with a plug of soil in the cylinder. The soil can be removed from the cylinder and the operation can be repeated to take samples from lower depths.

In recent years a number of researchers, mainly in the eastern U.S., have used manual post hole diggers to help locate sites in heavily vegetated areas. Since there is still little published literature on this approach, we are reporting their experiences to help indicate the uses and limitations of the technique.

There is a good deal of similarity to the uses of the technique by different workers. Surveyors establish transects across study tracts and test points at regular intervals along the transects (see Chartkoff 1978). In some cases, such as along freeway rights-of-way, single transects are used. In other cases, especially when wide areas are being surveyed, multiple transects are used. Some schemes use grid intersections as testing points, other schemes used parallel transects but unaligned starting points on each transect, and still others use series of transects extended from points in randomly-chosen directions. In all cases, the testing reflects the kind of point sampling discussed by Nance (1979).

The use of the technique grew out of its use to explore known sites. Such uses can be revealing because they indicate something about the sort of site which is sensitive to the technique. For example, Stanley South (1978) used a manual post hole digger for a within-site study at Fort Johnson, South Carolina. He took 80 core samples, part on a random-aligned transect pattern and part on an interval-aligned transect pattern (South and Widmer 1977).

His experience is of interest because it reveals something about the density of artifacts in such a site relative to the sensitivity of the technique. He obtained independent measures of artifact density by excavating 17 square test pits, each 3 ft. sq., as controls. Fort Johnson, where he tested, proved to be an extremely rich site, possessing about 238.5 artifacts per horizontal sq. yd. (26.5/sq. ft. or 288.6/sq. m.), compressing all depth into a two-dimensional plane. His test holes averaged nearly 5.3 artifacts per sample, a density which closely approximates the excavated test pit results. For a site of this density the test hole procedure is sensitive enough to measure considerable amounts of internal variation as well as to indicate the presence/absence of site attributes with high degrees of reliability.

Most sites are not as rich as Fort Johnson, however, so the experience of others has not always been so rewarding. Casjens et al. (1980) used a clamshell post hole digger during a survey of parts of Nantucket Island in which holes were dug along transects laid across a series of known historic sites. In this case, each site discovered by other means was also identified by the post hole technique, but data on artifact densities are not given. They believe that less rich or dense sites will not be found so reliably, which has been the experience of James Bellis (personal communication, South Bend, 1980), who has used the technique in surveys along the terraces overlooking the Ohio River Valley. Bellis has used a 4 in. diameter drill or auger to test for prehistoric flake scatters, with little success compared to other approaches such as pedestrian survey. Casjens et al. (1980:11) note that the post hole digger works well in sand, but not in rocky soil, although it can cut smaller

roots. It is sensitive to soil stains or midden, but is not useful for identification of site or soil profiles because the diameter of the hole is too small to allow much of the hole wall to be seen from above ground.

Wood (1976) used a post hole digger in his 1975 survey of the Laurens Shoals area of the Oconee River in Greene and Putnam Counties, Georgia. He describes his sampling strategy as a random-systamatic, unaligned point sample. In the survey, 22 quadrats were chosen for the post-hole study; each quadrat measured 100 m. sq. Within each quadrat, up to 25 post holes were drilled. Five N/S transects were established within each quadrat at 20 m. intervals, and post holes were dug at 20 m. intervals along each transect. The regularity of spacing was reduced by using a random numbers procedure to choose the location of the first point on each transect. In all, 354 holes were dug, and the backdirt from each hole was sifted through a 1/4 in. or 1/2 in. mesh (the reason for the use of two screen sizes and the number of holes screened with each are not presented). The work took 77 person-days of labor (616 work-hours), or about 1.72 work-hours per test. This figure includes such factors as travel time, brush-cutting, location, measurement, sifting and recording as well as the actual post hole digging.

Wood does not present quantified data on each test hole, so only summary figures can be discussed. He stratified his study area into three study areas, each of which held somewhat different sorts of remains: upland, riverine, and island (the last refers to islands in the middle of the Oconee River, while riverine refers to shore or bank zone habitat). In the upland area, he dug 175 post holes

in nine quadrats, of which 15 (9%) yielded cultural remains of any sort. He found that in the upland area, where sites were rather small and thin, an average of 1.9 tests per 100 m. sq. quadrat yielded some remains. This figure is govered both by site density and site frequency.

In the riverine stratum, six of nine quadrats yielded cultural remains in test holes. He dug 137 post holes, of which 32 (23%) yielded remains. An average of 3.6 test holes per quadrat yielded remains, indicating either more or denser sites in the riverine habitat (but we can't tell which at this point), than in the upland habitat.

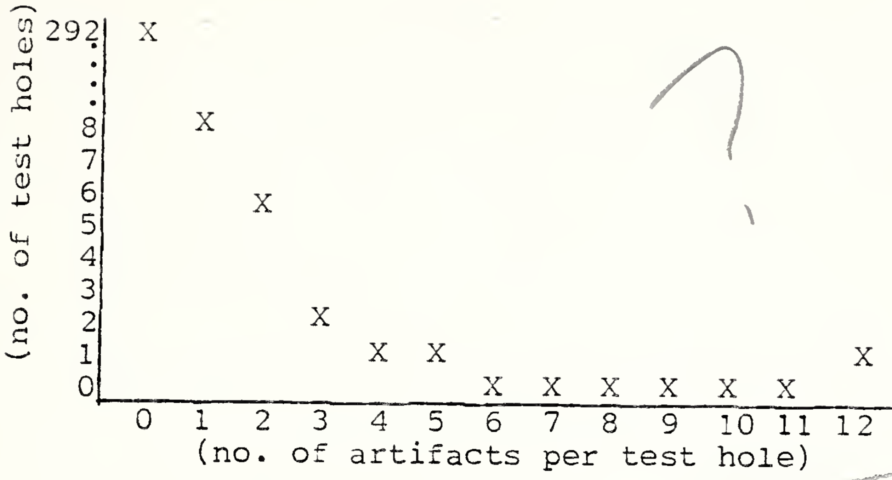
Five quadrats were tested in the island stratum, and cultural remains were found in test holes in four of the quadrats. He dug 42 holes, of which 11 (26%) yielded some archaeological evidence. An average of 2.2 test holes per quadrat yielded remains (Wood 1976: 41).

Wood also used the technique to delineate discovered sites and to discover internal structure and variability within sites. These contributions, however, are tangental to our present purpose.

Wood recognizes several limitations to the technique (1976:42). The interval he chose (20 m.) could cause sites smaller in diameter than the interval to be missed. He also recognizes that sites buried deeper than the post hole excavator can dig would not be discovered by it. He cites a study by Halley, Zurel and Gresham (unpublished) in which those researchers used post hole diggers to probe for limits of known sites of low artifact density and were not often able to find any site evidence in their tests (see Chartkoff 1978 for a discussion of this problem).

Even so, Wood enjoyed a high percentage of positive tests with his experiment. Overall, about 16.4% of his tests yielded cultural remains, and in one stratum the yield was better than one test in four. These figures indicate a high site density, a set of rich (artifact-dense) sites, or both. Hanson and Most (1978), working on a survey in Sumpter National Forest, South Carolina, did not face as rich an archaeological record. They used the post hole digging technique to survey in a heavily vegetated area. They laid out a series of 31 transects, each 1000 ft. long, and dug 6 in. diameter holes at 100 ft. intervals along each transect. This was done after thay had done a pedestrian survey along the same routes, looking opportunistically at disturbed soils for evidence of remains. They found that they could not dig post holes in swampy soils, which eliminated about 1/3 of the potential holes they might have dug. All dug-up soils were sifted through 1/4 in. mesh for examination to promote uniform standards of recognition. Their criterion for the discovery of a site was the recognition of the presence of artifacts, meaning that they did not also examine for stained soil, ecological remains or other possible site attributes. Their probes ranged in depth from 8 to 48 in.

They dug 310 test holes on this survey, of which only 18 produced any artifacts. The results can be expressed as follows:



While the sample is too small for statistical rigor and elegance, the nature of the curve is evident. It shows that there is an expectable inverse relationship between the number of artifacts or archaeological remains that turn up in a sample and the number of samples likely to possess site-defining attributes. Hanson and Most (1978:30) note that they did their tests in a tract of forest where, based on predictions from the results of pedestrian surveys and ad-hoc predictive modelling, they had the expectation of finding the largest, richest, densest sites in their study area. They expected that in other parts of the forest, where known sites were of lower artifact density, the technique would have produced poorer results.

To test this inference, they conducted a series of sub-surface tests at a site in another area, the Cracker's Neck Site (38-AK-195). It was in another area and from surface indications was presumed not to be very rich. At the site they established a series of intersecting transects to form a grid with 10 ft. intervals, and drilled a series of 36 post holes at grid intersections. All but four holes yielded

at least one artifact, suggesting that the site's average artifact density horizontally must have been in the range of 40-50 per sq. yd. The four sterile holes were all located at the presumed perimeter of the site, where artifact density would have been considerably lower. Although they did not draw this inference, we suggest that we can begin to learn at what artifact density the post hole technique starts or stops becoming reliable. Here we have a case of a site less rich than Fort Johnson but still rich enough so that all post holes not at the site's apparent periphery, and some at the periphery, yielded artifacts to tests whose surface area was about 1/5 sq. ft. per hole. When the site's artifact density (horizontally) is on the order of 40-50 artifacts per sq. yd. (or 4.4-5.5/sq. ft.), the technique appears to be highly reliable. For obvious reasons, if a site has a density on the order of 9/sq. yd. (1/sq. ft.) it cannot be reliable since a single hole has only a 1:5 chance of striking an artifact. The breakoff point should be in the range of 20-30 artifacts per sq. yd. (2.2-3.4/sq. ft.), and it may be possible to specify this figure more precisely either empirically or theoretically.

Hanson and Most (1978:30) carried out another set of tests at a second site, 38-AK-204, to test the technique's ability to discover artifacts in areas where dense surface vegetation, surface litter and forest growth prevented any surface artifacts from showing, but where a site was known to exist because opportunistic pedestrian survey located some artifacts in a patch of disturbed soil. The site was known at that point in terms of single point at which archaeological remains were discovered, rather than as an area within which remains occurred. They established a 900 ft. long transect across the site's terrace and over the find-spot, and

dug 10 holes at 100 ft. intervals along the transect. They found at least one artifact in eight of the ten holes, and one of the sterile holes was on the transect perimeter. The average yield per hole at AK-204 was lower than at Cracker's Neck, however, indicating that the technique works at an acceptable level of reliability with artifact concentrations of somewhat lower densities.

Their conclusions are worth quoting for comment:

> Overall, the subsurface testing was not a very efficient strategy for locating sites when exposed ground surfaces were present; however, in completely forested areas of predictably high site density and concomitant high artifact density, this procedure would offer a good first look at the location of sites. it cannot be expected to discover sites of low or moderate artifact density with any success....at the reconnaissance level of research where conditions permit an opportunistic, cleared ground survey offers the best possibility of locating sites. All of the 34 sites recorded during this study were located during this type of survey. Subsurface transect sampling provided very little information to the survey. The only significant result of this latter scheme was that it could regularly detect previously located sites. This fact supports the hypothetical model of sampling success which suggests that only high density sites would be located with any consistency. In any case even if sites are discovered using this approach, the sites would require considerable test excavations to gather useful archaeological data (ibid.)

Their work is one of the few available assessments of the sort of data that this technique will or will not detect (House and Ballenger 1976 is another example). These results are essentially qualitative rather than quantitative, as they recognize when they say that more experiments are needed to determine what the ratio is between artifact density in a site and the success that the sampling technique is likely to enjoy in discovering a site of that density (Hanson and Most 1978:26).

It is possible to extend their conclusions. The success of the technique depends not only on the density of artifacts in a site, but also on the attributes being measured. Hanson and Most relied

essentially on the presence or absence of stone or pottery artifacts to determine the occurrence of a site. This was largely a consequence of the kinds of attributes to be found in sites of their area, where such characteristics as soil color, shell fragments or firecracked rock are unreliable for this purpose. They did not test for other sorts of dense or continuously-distributed attributes such as distinctive soil chemistry. In other regions, or with other types of sites, the kinds of attributes that may be observed and the density of those attributes may vary considerably. The appropriateness of the technique depends partly on the nature of site attributes, which in turn means that decisions about appropriateness require prior knowledge about the attributes likely to be encountered.

Their comment that they did not find any sites that they had not found separately by pedestrian survey is also worth considering. The fact that they did relocate sites found by other methods can be taken as support for this approach rather than as a criticism, because confirmation of the existence of sites through redundant discoveries using different techniques adds confidence to the survey's results. The authors do not make this point clear, but it appears that they relocated every previously known site over which a testing transect passed. If so, the technique is not as ineffective for discovery as their conclusions seem to indicate. If they had used post hole surveying before doing a pedestrian survey, rather than afterward, they could have made predictions of site distribution based on the post hole data, and could have used their predictions as a basis for testing by pedestrian survey. The fact that the post hole technique provides a systematic sample gives it a statistical power

that pedestrian survey data may lack. Pedestrian survey in forested areas is dependent on the occurrence of exposed ground surfaces. They are highly variable in their occurrences, and their occurrences may bear no relationship to the distribution of archaeological remains.

Scott, McCarthy and Grady (1978) record the first use in Texas of post hole testing as a means of site discovery. They used a manual post hole digger to excavate 504 samples along grids or transects or in clusters of 5-6 closely spaced holes. Their work-rate was 40 holes per person per day, or 12 person-minutes per hole. Their study took place on several branches of Striker Creek in Cherokee, Smith and Rusk Counties. The interval they used between post holes ranged from as little as 1-2 m. to as much as 20 m. but most holes were 5-15 m. apart. The holes ranged in depth from 10 to 140 cm. and averaged 45 cm. They found artifacts in only 23 (4.6%) of the holes they dug. Artifacts occurred at depths ranging from surface to 80 cm. with most occurring at depths of 30-40 cm. (Scott, McCarthy and Grady 1978:16). We might note in passing that since casual shovel tests rarely go as deep as 30 cm., most of the finds made on this project would not have been made with shovel testing techniques.

By means of data analysis results and simulation models, they were able to evaluate the effectiveness of post hole testing versus pedestrian surveys according to density of ground cover and artifact density within sites. In their area, they dealt with three basic topographic types of terrain: bottomlands, uplands and the slopes connecting them. They found that ground visibility was greatest in the uplands and lowest in the bottomlands due to the relative

density of ground cover. They also found a direct relationship between ground cover and site density: site density was greatest in the bottomlands in spite of survey difficulty due to dense ground cover. The technique of pedestrian survey increased in productivity or efficiency at a logarithmic rate from the bottomlands to the uplands (op. cit.:51). They divided their three topographic types into two subsets each: cleared and wooded. For each category they asked whether the pedestrian survey technique, the post hole digging technique or a combination of the two was most productive for finding sites under those conditions.

The results show, nor surprisingly, that when the ground is cleared in any kind of terrain, visual examination in a pedestrian survey provides a more reliable means of site discovery for sites on the exposed surface than post hole digging does. When ground cover was thick but site artifact density was high, post hole digging was superior. When ground cover was dense but artifact density was low, post hole digging was not as effective as visual examination of disturbed ground for discovery purposes. Their results show a proportional measure of the utility of the post hole technique but not yet a quantiative one.

Scott et al. (op. cit.) noted the proportion of holes that fell within the perimeters of known sites yet did not produce site evidence. They found that over 50% of the post holes they placed within known sites yielded some cultural evidence in the form of artifacts. For reasons they do not discuss, however, they feel that their findings were abnormally low. They point to work done at Lake Fork Reservoir in east Texas by Bruseth et al. (1977) in

which post hole digging was used to explore the subsurface structure of sites. There it was found that nearly 75% of the test holes within the known sites' apparent perimeters had yielded some cultural remains.

In response, it could be pointed out that the differences in "success rates" (that is, in the number of holes dug within known sites that yield cultural evidence) is generally a function of attribute density within sites. Since sample size cannot be adjusted with a post hole digger, compensation can be made by adjusting sample fraction or by a statistical weighting factor.

Core Drills:

Core drills differ from post hole diggers in that a core drill is a hollow tube that is driven or drilled into the ground and from which a core or plug of soil can be extracted and removed whole. The principal use of core drills in archaeology to date has been the exploration of the internal structure of known sites and
Price et al. 1964; Redd et al. 1968
features (e.g. Deagan 1976, 1979; Percy 1976). They have begun to be used for site discovery as well (e.g. Dincauze 1980; Wood 1975). There are both manual and power-driven versions of core drills. The manual and portable power-driven models generally extract small-diameter cores, on the order of 1-2.5 in. in diameter (2.5-7.0 cm). There are truck-mounted core drills that extract larger-diameter cores, but they are expensive to operate, limited in use and will be considered in a separate section.

Core drills have certain advantages for archaeological survey. They are relatively inexpensive to purchase and operate. They are generally highly portable. The extraction of a core is rapid. Soil

removed by a core drill can be examined as a single piece, so visible stratigraphy may be detectable. The soil may also be used for chemical tests, giving the value of redundancy to the technique. Through the use of extensions, core drills can often be used to greater depths than post hole diggers, making them especially useful in alluvial settings.

The technique also has some serious limitations, however. Most important is the usually small diameter of the core drill. The small diameter means that many artifacts cannot be extracted. This makes the tool unreliable as a means to discover sites through artifact observation. The tool's small sample of dirt increases the problem of sampling error in general. A 2 in. diameter core has less than 1/6 the surface area of a 6 in. diameter post hole. Core drills cannot be used well in rocky soil. Their chief attraction, however, is their ability to locate midden sites in alluvial situations, so this limitation is not so serious.

The kind of attribute that the core drill is best suited to recover is the fine-particle, continuously-distributed or very high density attribute, such as soil stain, ash concentration or shell midden. If such sites as middens are expected in a study area, and especially if they lie covered by alluvium so that they are not likely to be discovered through surface observation or shallow subsurface exploration, the use of the core drill can be valuable in site discovery. Otherwsie, other techniques are generally more productive.

Several surveyors have experimented with the core drill. Dincauze et al. (1976), Luedtke (1975), Casjens et al. (1980) and Peter

Thomas (personal communication, 1980), for example, have used the technique in New England, finding it fast and inexpensive but generally inaccurate for site discovery.

Users of core drills in survey have commented consistently that the tool has very limited value in site discovery, by which they usually mean that it is not very reliable for the discovery of many kinds of sites. Apart from its limited utility where rocks, gravel or heavy roots occur in soil, the two important limitations of the technique concern attribute recognition and sample size. As we noted before, the tool does not readily recognize or recover many kinds of artifacts, and since artifact recognition is the most common means of site identification, the tool does not fulfill this means very well. It does do a reasonable job of recovering certain kinds of attributes, however, such as midden, ash and stained soil. It would be more appropriate to say that this tool is of limited utility because the circumstances in which it is effective are limited, but that where such circumstances are expected, the tool may be very appropriate.

The matter of sampling is different. Core drills typically recover tiny samples. A typical drill with a 5 cm. diameter has a surface area of 19.635 cm.^{2}. If one were testing a quadrat 500 X 500 m. in area, and sampled at 20 m. intervals throughout the quadrat, one would take 676 samples with a total surface area of 1428.326 cm.^{2} or roughly 15% of one sq. m. Since a 500 m.^{2} quadrat contains 250,000 m^2, the core sample would amount to only 1/1,675,000 sample, which, for an unstratified sample, is far too small to be reliable.

Power Augers:

A power auger is a drill mounted beneath a motor. The sort suitable for archaeology are portable to some extent, hand-held, and powered by gasoline motors. They are not very easily used overland but rather require transportation by vehicle to the site of use along with sufficient gasoline. Typically such drills are operated by two persons, although some one-person drills can be found. Most drills carry axle-core bits with six-inch diameter, but some 9 in. and 12 in. bits can be found. Most models have a maximum depth of between 45 and 60 in. depending on bit length, available extensions and the power of the motor to turn a longer drill.

A power auger provides an inexpensive means to test below the surface quickly. The power drill digs a post hole in a fraction of the time and effort needed for manual digging. The machine is not prohibitively expensive: currently, models cost about $400-600. It can be used in rockier soils than hand diggers or core borers although it tends to become fouled in mucky soils.

A 6 in. auger drill has a surface area slightly smaller than 1/5 of one sq. ft. It is large enough so that many kinds of artifacts can be recovered with the tool. It also is useful for the recovery of continuously-distributed variables such as shell midden, stained soil and ash, or high-frequency attributes such as may be the case for pottery, lithics or fire-cracked rocks. Soil for chemical tests can be recovered with this tool. The technique, however, does not produce a solid core, so some vertical mexing occurs as dirt is lifted by the drill bit out of the hole. Some users examine the recovered soil visually, while others also sift the soil. There

is general agreement that sifted samples are more reliable than samples examined only visually (e.g. Assad and Potter 1979; Casteel 1970; Claassen and Spears 1975; Deagan 1979, 1980).

The technique is limited by both its physical nature and logistics. Because it recovers a small sample, it is not a reliable means of locating small and low-density sites. Its surface area is considerably larger than that of core drills as a rule, however. Sites that are small are apt to fall between interval samples, a problem that occurs with any interval sampling technique. An advantage of power auguering in this regard is that, due to the speed with which it can be done, it is very economical to reduce the interval between samples. This cannot be said of shovel-excavated sampling techniques.

The problem of the surface area of the test is not so easily controlled. Power auguers, like all hole-digging techniques, make small-surface-area holes. When holes are drilled in sites of low attribute density, a considerable chance exists that each hole will fall between attributes and therefore fail to reveal the existence of the site. This problem can be only partially overcome by increasing the number of holes drilled. Although the odds increase against it, it remains possible that each additional hole will fall between attributes. The alternate tactic, that of increasing the surface area of the unit, increases the probability that an artifact will turn up even if the hole occurs in a site with widely-dispersed attributes. The only practical way to do this with a power auger is to use a bit with a larger diameter. For example, a 6 in. bit covers a surface area of about 0.19 sq. ft.; a 9 in. bit covers a surface area of about 0.44 sq. ft.; while a 12 in. bit covers a surface area of about 0.78 sq. ft. The problem with the increase

in bit size is the dramatic increase in the weight of the bit and the consequent reduction in crew mobility. However, since a power auger is not a practical cross-country survey tool in general, and usually requires the use of a service vehicle within 1/4 mile or so, the increase in bit weight may not be a serious problem. A typical machine with a 6 in. bit weighs about 70 lb., and its gasoline weighs about 7 lb./gallon.

Even though surface area can be manipulated to some extent, the auger is a poor tool for the discovery of large features such as architecture. The sample size is still too small to allow for much effective visual resolution of large features. It therefore remains most effective for the discovery of high-frequency artifacts and other site attributes. Perhaps the major exception is the observation of vertical stratgigraphy. Due to the narrowness of the auger hole, its sidewalls cannot usually be seen well enough to permit the recognition of stratigraphic profiles.

As with core drills, most uses of power augers in archaeology have been for within-site explorations. For example, Keith Johnson used a power auger to define the distribution of midden at site CA-LAn-2 in southern California (K. Johnson 1966). There, in a meadow, it was possible to drill and interpret about 20 holes per hour. At that rate, it would be possible for two people to lay out a 1000 ft. transect, drill holes at 20 or 25 ft. intervals, sift the soil and record the results in a half to one work day.

This was the experience of Taylor and Smith (1978) in their survey of the proposed Russell Reservoir in Georgia and South Carolina. Thier survey covered 40,000 acres of heavily vegetated terrain that

included ridges, steep slopes and alluvial floodplains. Their work is particularly interesting because, in their testing of promising areas they drilled over 400 holes and did not find a single artifact, in spite of the fact that 489 historic and prehistoric archaeological sites were recorded based on observations made during pedestrian surveys. This result offers a serious challenge to the value of the power auger technique, so some evaluation is in order.

Taylor and Smith (1978:187-8) used the power auger technique as a site discovery procedure. The auger was used along a series of 1000 m. long transects which were laid out from the Savannah River away in randomly chosen angles. Holes were drilled along each transect at 50 m. intervals. The technique was not used uniformly throughout the 40,000 acre area, but was done widely enough that some drilling occurred in each type of habitat within the proposed reservoir.

Much of the drilling was done on the floodplain. Surface vegetation there was very dense and it was hoped that the drilling technique would reveal the locations of sites not observable otherwise. Unknown at the time to the surveyors, alluvial deposits on the floodplain were deeper than the drill could dig. This was because farming in the last century or so had caused widespread erosion, leading to the recent deposition of thick layers of alluvium over prehistoric and early historic land use surfaces. The subsequent use of well drills showed that as much as 5 m. (16 ft.) of alluvium lay in some areas. The power auger was therefore useless in that terrain.

It also proved unfruitful in areas of sloping terrain because heavy erosion, which had contributed to the alluvial deposition just noted, had stripped soils from the slopes, leaving an extremely rocky subsoil behind which lacked an artifact-bearing stratum and

in any event was so rocky that the power auger could not be used effectively. Erosion also caused many parts of the uplands and ridges to lack drill-able A-horizons to their soils. Where such soils existed, the apparent low density of artifacts contributed to the failure of the small-area drill to locate sites (Taylor and Smith 1978:187-9). The authors noted that they had considered the use of a backhoe in deeply alluviated areas, but did not proceed because they felt its use would have required so much sifting as to make it cost-ineffective, as well as because of the destructiveness of the technique.

Other researchers have had better results with the use of the technique. Kathleen Deagan, for example, has used it in site discovery in Florida for six years:

> I have found, over the years, that surface reconnaissance in those areas that are visible (roadsides, phone line transects, gopher burrows) (gives) and extremely poor indication of sites in the survey areas, and now we rely almost exclusively on the mechanical soil auger....Many people I have spoken to about this in Florida object to the time and hard work involved in the... auger survey method, and I must admit that it is rather time consuming. It has, however, been very reliable and in 6 years of this sort of work no subsequent construction activity has unearthed cultural remains that were missed during survey (Kathleen Deagan, personal communication, Tallahassee, 1980).

Her technique proceeds as follows. First, she designs a grid over her study area. The grid interval is at least 5 m. and never more than 10 m. The intervals may be modified to adjust for undrillable barriers such as paved streets. She has found it necessary to lay out the transects with a transit, because in dense ground cover such as palmetto and live oak it is not possible to plot transects ac- accurately with tape measures and hand-held compasses alone. Then, where needed, a swath is cut along the transect using a trimming tool such as the "Green Machine." The swath is 4-5 ft. wide. The

augering points can then be set along the transect by tape or transit. For augering she uses a 5.5 hp. Homelite drill, in some cases with a 3 in. bit and in other cases with a 5 in. bit. The Homelite drill bit has a 56 in. shaft length, indicating maximum possible depth. The drill is fouled by wet soils, so in such a situation she drills with a 2 in. diameter soil borer driven by hand, such as the model from Art's Machine Shop in American Falls, Iowa. Her work-rate she estimated from her most recent survey in dense vegetation, which took a crew of two workers 5½ weeks to test an area of 80 acres. The work-rate averaged 8-9 holes per person-hour including all labor.

Deagan (1976, 1979) used the power auger technique in a survey of Fort Matanzas National Monument near St. Augustine, Floria. The area covered roughly 80,000 sq. m. She used a grid with intervals averaging 10 m. and used a gasoline-powered auger to drill each hole. Holes were drilled with a 3 in. bit and all excavated soil was sifted through 1/4 in. mesh. A dense blanket of live oak and palmetto covered the site, within which historic and prehistoric remains were known to occur. Here survey was used as a site discovery technique rather than to explore within a known site. Test excavations were made to gather further data where auger borings showed remains to occur.

Deagan drilled 888 holes during the survey, of which 174 yielded some sort of cultural remains, ranging from road fill and recent trash dumps to prehistoric shell midden and prehistoric and historic ceramics. The drilling operation led to the identification of two shell middens, a modern trash dump, a recent but abandoned roadway, and areas of historic Spanish military operation. Each test hole had a surface area of ca. 44.17 $cm.^2$, so the 888 test holes covered

a total area of ca. 3.9 m.^{2} for a sample of roughly 0.000049% of the total area of 80,000 m.^{2} The drilling of the test holes took 256 work-hours for a crew of two, or a little less than four holes per person-hour.

The fact that nearly 19.6% of the auger holes yielded some cultural evidence is quite high. It clearly is due to the fact that the survey area was confined to a historical locale.

Deagan also used the technique to survey portions of the city of St. Augustine, Florida, to try to locate the boundaries of the original 16th Century settlement (Deagan 1980). The survey was preceeded by extensive archival research, from which hypotheses about the structure of the settlement were framed for testing by the auger method. About half the test area was inaccessible for testing due to the occurrence of impenetrable urban features, but in the remaining portions a series of transects were established, along which auger borings were taken using a 4 in. bit (8.8 cm.) with a 51 in. (112.2 cm.) length on a powered auger. Grid intervals ranged from 5 to 10 m. depending on local conditions. The excavated soil was hand-sorted in this case rather than sifted.

This survey covered an area of 1296 m.^{2}, of which 710 m.^{2} was excluded due to impenetrable features (54%). The power auger is able to drill through packed earth, such as dirt driveways, but not through pavement (Deagan 1980:5).

Deagan found that 376 of the 585 test borings she drilled (64.3%) yielded datable cultural materials. Her analysis of the auger data not only allowed her to distinguish the sought boundaries of 16th Century St. Augistine, it allowed her to test interpretive hypotheses

concerning the site's organization, and to frame other hypotheses that she subsequently tested through excavations. While these benefits are of subsidiary interest to the present study, they may be of particular interest to cultural resource managers who wish to maximize the returns of their data collection efforts.

In both cases Deagan was working with particularly rich concentrations of archaeological remains. The high yield of her sampling efforts are, of course, functions of the richness of the locales rather than the excellence of the tool. The significance of the percentage of positive tests is that in sites of this richness even small-diameter drills are sufficient. Other archaeologists have used the technique is areas with less-rich remains, although it is still not yet clear what the lower effective limit is for highly reliable discovery. For example, Larry Loendorf has used the power auger as a standard survey tool in North Dakota, and Stan Ahler has used it at the Knife Rivér Indian Reservation at Lake Ashtabula, North Dakota (L. Loendorf, personal communication, Bismarck, 1980). Michael B. Collins (personal communication, Lexington, 1980) reports using the power auger primarly for within-site testing but sometimes for site location, in Kentucky. Ives and Evans (1980) have tested with it in Missouri, and Casjens et al. (1980) report on its use in New England. General experiences indicate that the technique is not reliable as a means to find low-density sites but that in many environmental settings it is the most effective available technique. We will return to this theme after a discussion of well drillers.

Power Well Drillers:

A power well-driller is a truck-mounted power auger with a large-horsepower motor and a capability of drilling to depths beyond archaeological significance. Well drills may be solid core or hollow core. Typical rigs have drills with diameters of 6 in. to 12 in. Commercial well drillers in many parts of the country charge anywhere from $10 to $50 per foot to drill, depending on conditions. The tool is of interest to archaeologists because it is the only practical sampling device available capable to searching for archaeological remains at depths greater than 10-15 ft.

Archaeological survey projects occasionally encounter situations in which a former ground surface, which may have been occupied by prehistoric people, has subsequently been deeply buried by soil deposits such as alluvium or landslide. For example, the Makah Indian village of Ozette, in Washington State, was buried by a wall of mud in the 17th Century (Kirk and Daugherty 1978). At San Francisco Bay, construction of the Bay Area Rapid Transit (BART) system revealed the existence of a prehistoric burial at a depth of 14 m. (44 ft.) below the present surface (Bickel 1978). It transpired that 4000 years ago the exposed land surface at San Francisco was 13 m. lower than today at that location, and that much of the overburden was deposited only in the last 130 years.

The existence of a particular burial might not be predictable, but the existence of a buried land surface is usually a matter of geological record. In such cases, it is often quite probable that an alluvially buried land surface contains past remains. When the overburden is more than 10-15 ft. deep, the use of a power well drill

provides an effective means to test for the existence of remains. The operation of a well driller is expensive in absolute terms, but it may well be cost-effective. For one thing, it is far less expensive than the use of hand-excavation to the same depth. For another, it is far less expensive than the stoppage of construction projects in progress, which may cost tens of thousands of dollars per day, which may result if construction strikes a deeply buried archaeological deposit.

The well-drilling technique is limited as a sampling device by the size of the drill, as are all other hole-digging techniques. Thus its distinction lies in its ability to probe more deeply than other approaches.

The only example we discovered of the use of a well drill in an archaeological survey was by Ferguson and Widmer (1976), who used one to test some alluvial areas during their survey of the Bobby Jones Freeway route near Augusta, Georgia. Their survey was hampered by heavy vegetation through the entire right-of-way, and also by alluvium suspected to be of recent origin in some areas. To test these possibly deeply buried surfaces, they used a core drill with a 6 in. bit mounted on a four-wheel-drive truck frame and powered by a diesel engine.

They first tested the technique at a known site called Taylor Hill (9-RD-4). There, a 50 ft. long transect was laid out across the center of the site, and a series of holes was drilled, each 12 in. deep, at regular intervals. The transect was surface-collected over an area 50 X 1 ft. as a control. This collection yielded a surface density of 0.9 artifacts per sq. ft.

Of the ten holes drilled, two were sterile and the others had between 7 and 25 artifacts each with an average of 14. The mean for all ten of the samples was 11.2 artifacts. This figure indicated that the horizontal artifact density for the site was about 56 artifacts per sq. ft. rather than the 0.9 indicated by the surface data. Their analysis indicated that in sites of such high artifact density, the six in. drill had an 80% chance of correctly indicating the existence of the site with a single boring (pp. 24-27).

To gain a clearer idea of the lower limits of reliability of the drill technique,Ferguson and Widmer (1976:27) conducted a second series of tests at six previously reported sites of apparent lower artifact density located on a series of bar ridges at nearby Phinizy Swamp. Ten of the 18 test borings produced artifacts, at depths as deep as six ft., including one site whose existence had not been previously known because it was not detectable at the surface. The densities of these seven sites are not give, although all are regarded as less dense than Taylor Hill, indicating as we have seen earlier that as artifact density declines the reliability of the technique to encounter artifacts declines, even if at an uncertain rate.

Ferguson and Widmer (1976:27-30) then used the technique to drill 71 more core samples at 22 localities. They found cultural remains in 34 of the samples (48%). The samples provided confirming evidence for the existence of 12 sites peviously known from surface indications but four other surface scatters known through pedestrian survey failed to yield any indicators in the core samples. Four other locations predicted to yield sites due to predictive modelling failed to produce any evidence in the drilled core samples, and two other

localities predicted to lack sites failed to produce any evidence in the cores.

None of the sites was test-excavated, so there are no independent measures of artifact density against which the core results can be evaluated. The data on the contents of the various core samples, when pooled, reveal that artifact density in the samples ranged from a high of 67.56 artifacts per cubic foot in site 9-RD-8, to 0.95 per cu. ft. in site 9-RD-5. It also appears that some sites, although tested by core borings, had few enough artifacts that due to chance alonenenone were represented in core samples. It can be assumed that the densities of those sites may have been about one or two artifacts per cu. ft., if not less, and that this level may represent a point at which the six in. core drill ceases to be a reliable tool for site discovery.

Comments on Core or Post Hole Sampling:

This review of several techniques for digging or drilling so-called post-hole or circular samples as a site discovery means allows a few general comments to be made about the use of hole-drilling in general for this purpose. If hole-drilling is a suitable technique in certain cases, it then becomes possible to discuss which form of hole-drilling is most appropriate. However, all techniques accomplish the same thing: the production of a soil sample for visual examination. In this regard, hole-drilling must be weighed against the use of the only other widely-practiced form of systematic sub-surface testing: excavation by shovel. A few researchers have begun to evaluate these approaches against each other (e.g. Claassen and Spears 1975; Ives and Evans 1980). In general, however, we must speak in terms of general principle and individual experience.

In general, a shovel test covers a larger surface area than a drilled hole, and it will consequently reveal the existence of low-density sites more reliably than auger holes or post holes will. Simpler forms of shovel tests can be excavated about as quickly as holes can be dug or drilled. All else being equal, shovel tests are therefore to be preferred.

All else is rarely equal in archaeological survey, however, and there are cases in which testing by drill or post hole digger is preferable. For example, rapidly-dug shovel tests are necessarily shallow -- generally 20-30 cm. deep (8-12 in.). There are many situations, however, in which archaeological remains can be expected to occur at greater depths, and in those cases post hole search becomes preferred by default over shovel testing. There are also cases in which the predicted remains are visually distinctive and of high density or continuous distribution, in which case the most rapid subsurface testing method is the most cost-efficient. In this situation the use of a power auger is the most rapid technique. The fact that the sample size is small can be compensated by adjustments to the sample fraction and by the application of weighting factors. The use of augering procedures for site discovery, then, should have an important place in archaeological survey.

SHOVEL EXPLORATION TECHNIQUES:

The use of the shovel to aid in site discovery is perhaps the most common adjunct to pedestrian survey now in use, and probably has the longest history of such techniques. Archaeologists in various parts of the eastern U.S. have been practicing shovel testing systematically for at least a decade, and some for much longer (McManamon

1980). One of the first archaeologists to draw national attention to the technique for site discovery was Lovis (1976), reporting on its use in northern Michigan in conditions of heavy surface vegetation. As with other techniques, shovel testing had been in use for within-site study before it came to be used for survey, although in this case the use was of particular importance since the shovel is the main tool for excavation (e.g. Meighan 1950). Systematic shovel testing has become fairly common in the eastern U.S. although it is still rather unusual in California as strictly a site discovery procedure.

Shovel testing has several advantages as a surveying technique. The equipment is inexpensive, durable, highly portable, and is easily used in almost any terrain. The amount of surface area included in a shovel test can be easily adjusted, although time expenditure increases correspondingly. It is capable of revealing visually-sensed site attributes, most commonly artifacts but also distinctive soils, ash, shell, bone and fire-cracked rock. Under some circumstances features can be detected, and it is possible in some cases to observe stratigraphy in the sidewalls of test units. Because unit size is adjustable, the technique can be used to detect low-density concentrations of remains.

Two limitations to shovel testing are most important. First, the technique is comparatively costly in that it requires hand labor and its sensitivity tends to be proportional to the intensity of its application. Second, it works at generally shallow depths unless large-sized test units are excavated at great expense. It therefore is not capable of reliably detecting the existence of sites located at depths much below 20-30 cm. (8-12 in.). Since

these conditions occur in a number of circumstances, it is best to say of shovel testing that its application is limited and its utility must be evaluated within those limitations.

There are several kinds of shovel tests that different researchers have used. We have combined them into three basic forms, which we will call shovel scrapes, schovel divots and shovel probes for the sake of consistency. We exclude from this list the excavation of formal, straight-sided pits in regular levels as being an element of within-site exploration as opposed to site discovery.

The Shovel Scrape Technique:

A shovel scrape is made by using the shovel to scrape off the vegetation at the surface of the ground so as to reveal bare dirt but not to dig into the bare dirt so as to reveal the subsurface. The bared dirt can then be examined visually to determine whether any site-determining attributes are present. Generally, it is the presence or absence of artifacts that indicates a site's existence.

A typical shovel-scraped area measures about 1 X 1 ft. (30 cm.^{2}). The sampling strategy normally involves the establishment of transects across a survey tract -- either a single transect, a series of parallel transects, radiating lines from points, or a grid. Scrapes are made at regular intervals along each transect. Intervals reported are rarely less than 25 ft. or more than 100 ft.

Apart from the advantages of shovel tests in general, there are two important advantages to the shovel scrape. First, the technique is very rapid; a single scrape can generally be made and read by one person in 1-3 minutes. In many cases a worker can lay out a

1000 ft. transect, scrape, read and record exposures made at 50 ft. intervals, within an hour, so the amount of observations two workers could make in a day by this technique would be several times greater than could be done by power auger. The other important advantage is the fact that the size of the exposure can be easily expanded, making it useful for cases of predicted low-density sites or concentrations.

The technique also has several limiatations worth noting, however. First, it is very superficial; it does not explore beneath the surface to any extent, so it is not capable of reliably detecting sites that lie even a few inches deep. Furthermore, the technique fails to provide soil for testing or screening, and therefore yields less potential information than do techniques which yeild soil samples.

<u>The Shovel Divot Technique</u>:

The shovel divot technique is similar to the scrape technique except that it provides a three-dimensional sample rather than a two-dimensional surface. In this approach, a sharp-bladed shovel is used to cut a square-sided, inverse pyramid, or divot, of soil from the ground. The divot is lifted by shovel and turned over on the nearby ground, exposing its underside and the interior of the resulting hole to visual examination.

The chief advantage of the divot over the scrape is the fact that it cuts into the soil so that the actual sub-surface is being examined. In addition, the divot can be replaced after examination, making this technique the least destructive of all digging or drilling discovery techniques. However, it does not reveal a very deep

cut. Typically a divot cuts 6-8 in. (15-20 cm.) below the surface, rarely more. The cutting of a divot does not take significantly more time than the cutting of a scrape. The actual cutting of a divot, turning it over for examination, its examination and replacement should take 1-3 minutes per unit.

Like the scrape, the shovel divot does not provide soil for sifting or other mechanical examination, or for secondary use in chemistry tests. Its advantage over the divot is therefore quite limited in any real sense.

The Shovel Probe Technique:

We are using the term "shovel probe" to refer to search techniques in which soil is excavated from the ground and is mechanically examined in order to learn whether attributes of sites or archaeological remains are present. The soil from a shovel probe may or may not be sifted. The probes may involve the excavation of squared test pits as in formal excavation, the collection of standard volumes of soil if not formal unit shapes, or the excavation of irregularly-shaped units. In general, surveyors who use shovel probes use them in series at regular intervals along transects, and sacrifice shape and standard volume for speed and efficiency. The minimum size of a shovel probe tends to be governed by the size of the shovel. Most users report using a unit size of 25 cm.^{2} or 30 cm.^{2}, which means approximately one shovel blade in width or a little more. A surveyor can cut a roughly square hole roughly 30 cm.^{2}, pile the dirt next to the hole, examine it by hand or by sifting, and refill the hole, usually in 5-10 minutes, depending on conditions. Some surveyors have opted to use larger-sized units in

order to maximize the discovery probabilitieis of low-density sites. in such cases, they have used units 50 cm.^{2}, or roughly two shovel blades in width. Since a unit 50 cm.^{2} has four times the surface area of a unit 25 cm.^{2}, it takes longer to excavate. The difference is not quite four times as long, since much of the time it takes to dig and explore either unit is occupied by tasks that are rather constant in duration. However, most surveyors who use 50 cm.^{2} shovel probes report that it is difficult to complete one in much less than ten minutes.

Like the shovel divot, the shovel probe cannot be excavated very deeply. In operation, excavations of a small size cannot be excavated much deeper than 1/2 to 2/3 of their width, because there is not enough room to position the shovel at the proper angle for digging deeper. The need to dig more deeply can be met only by widening the unit, at a loss of time that begins to increase nearly geometrically with increase in width, until the unit becomes larger than the shovel handle is long. Units of this size are too time-consuming and costly for survey, so they are limited to excavation. As a result, it is rare that a shovel probe is dug more deeply than 20-30 cm. This means that the shovel probe technique really is sensitive only to sites situated at the present ground surface or immediately below it.

Shovel probing is more time consuming than scrape or divot techniques, or post hole digging, and is far more time-consuming than the pedestrian survey of the same surface area. However, since its sample size is much larger than that formed by post holes, and the size can be adjusted easily, it is more sensitive to low-density concentrations than any post-hole technique. It is therefore more

sensitive than pedestrian survey for sites obscured by surface vegetation. The technique provides soil for chemical assay, which the post hole techniques also do, but which scraping, divoting and pedestrian survey do not.

Like all mechanical sub-surface probes, shovel probing's effectiveness depends upon the density of attributes in concentration. It responds to visually-sensed attributes, and attribute density must be estimated in order to select a unit size appropriate for reliable discovery. For example, Chartkoff (1978) used the technique to explore for the limits of an Italian Paleolithic site called Petriolo II. At this site, approximately 150,000 stone artifacts were distributed across a field of about 15,400 $m.^2$ area in a shallow layer. The average artifact density was nearly $10/m.^2$ However, artifact density was highly variable. Shovel probes that produced samples of 50 l. volume were able to recover artifacts within the site reliably onl in those areas whose horizontal artifact density was greater than $10/m.^2$. For parts of the site with lower densities, the sample size of 50 liters (about 12-13 gallons of dirt, equal to a unit roughly 50 $cm.^2$), the sample size proved inadequate to detect the site within its boundaries, and its inadequacy increased as density decreased.

A number of surveyors have used shovel probes for site discovery itself. For example, Poplin, Norris and Wolfe (1978) used the technique in a survey of 600 acres of low-lying coastal plain in Berkeley County, South Carolina. Due to heavy ground cover on the former plantation they were surveying, they used 1 $ft.^2$ shovel probes along transects for site discovery, varying transect and interval width according to conditions. They expected to find numbers of

small, low-density sites, based on knowledge of the area's archaeology in general, and chose the shovel probe approach as the most effective one available within the constraints of their contract.

Circumstances led them to use three different transect intervals and unit intervals in their survey. In all, they dug nearly 300 units. Although they found seven prehistoric and historic sites in the area by pedestrian survey, none was located by the shovel probe technique. It could be suggested in retrospect that the surveyors were using too small a probe unit for their purposes. They attempted to deal with the problem of sample fraction by manipulating the number of units and the interval between them, but they did not deal with the problem of sample or unit size. Sample size, however, is the most relevant variable in the adjustment of a sample fraction in a shovel probe to permit effective recognition of low-density archaeological remains. Sample fraction, by contrast, needs to be adjusted to deal with the density of concentrations in an area and the size of concentrations, rather than the density of remains within concentrations.

George Teague, cited in House and Ballenger (1976:63), used a combination of the scrape and probe techniques to augment a probabalistic survey of the ParrOFrees Nuclear Power Facility. He dealt with heavy vegetation by scraping the vegetation clear from areas 10 m. in diameter, and then by digging 1 m.^{2} shovel probes at randomly selected points within each of the 30 so-cleared areas. He found cultural remains in 23.3% of the units. The sites he discovered were mostly low in attribute density. His experience indicates that the expansion of unit size increases the probability of the discovery of such concentrations.

Taylor and Smith (1978:188) used the shovel probe technique to test for the existence of a suspected site. Their report records the labor expenditure for this work. They opened a 1 X 2 m. test pit which was excavated to a depth of 3.0 m. and the excavated soil was screened to a depth of 125 cm. This work consumed 12 person-hours, allowing for the fact that only 40% of the soil was screened. We estimate that the excavation alone took about 1 to 1.25 person-hours per cubic m. while the combined excavation and screening took 2.5-3.0 person-hours per $m.^3$. If this were converted into the equivalent number of 50 $cm.^2$ units such as might be dug along a transect during a survey, the work would average about 11.25 person-minutes per unit to dig and screen if unit depth averaged 25 cm. Our experience is that for shovel excavation and midden sifting, these figures are correct within an order of magnitude, but do not take into account the time needed to record the work, or to locate and establish each unit. Location and write-up time are more or less invariate regardless of unit size at this scale. In dense brush it may take 10-15 minutes to walk 50 m. to the next unit. Thus the actual work calaculations should take into account the total work performance, not just the time consumed by the processing of one unit.

House and Ballenger (1976) used shovel probes to supplement a pedestrian survey of the route corridor for proposed Interstate 77 in the South Carolina piedmont. Their pedestrian survey involved the survey of each of a series of quadrats 650 X 650 feet spread along the 49-mile-long highway route. Each quadrat covered 9.7 acres (3.3 hec.), one quadrat per lineal mile of route, to be equal

to 20% of ths surface area of the heavily vegetated route corridor. Within each quadrat, one or two 1 m.^{2} test probes were excavated by shovel. The shovel probes were located along the diagonals of the quadrats, at selected points halfway between the quadrat center and a corner.

House and Ballenger (1976:44) report that they designed the sampling system keeping in mind discussions by Goodyear (1975) and Thomas (1975) about "non-sites". Their method was designed to identify such "non-site" concentrations as well as conventional sites. They do not discuss how their test pit strategy furthers this goal, except to say that it would help to locate non-sites as well as sites. However, information in their report helps to allow estimations of the productivity of their approach.

House and Ballenger excavated a total of 66 shovel probes in the 50 quadrats. They do not report why some quadrats had only one or no shovel probes. In addition, they excavated 44 test probes at places where the route crossed streams, because previous information on regional archaeology indicated that stream crossings were areas of high site probability. The 110 shovel probes were excavated to an average depth of 4-6 in. The excavated soil was examined closely by trowel, but was not screened. The report does not describe the contents of each unit, nor does it describe the contents of discovered sites in such a way that the sites can be scaled according to the sensitivity of the technique. Therefore only some general observations can be made.

The testing program led to the discovery of five of the 22 sites discovered within quadrats, and five of the 19 sites discovered at stream crossings (one stream crossing site also was within a quadrat,

so the total number of sites discovered was 40 rather than 41). Of the 40 sites, nine were historic, and four of the historic sites also had prehistoric components; the other 31 were prehistoric. None of the historic sites discovered by test probe was historic. The historic sites included five with stone foundations, chimney ruins or standing walls, which were sufficiently obtrusive that surface vegetation did not obscure them and they were discovered by pedestrian survey. The other historic sites were manifested by scatters of crockery which appear to have been very distinctive against a background of vegetation and also were easily found by pedestrian survey.

Ten of 31 prehistoric sites (32.3%) were discovered by test probes. None of the prehistoric sites was as obtrusive as the historic sites, although some were as dense. Five of the 31 sites were find-spots of single artifacts, and two of the five were found by shovel probe. If a single stone flake occurs in a shovel probe, it stands a high chance of being found, whereas if it lies on the ground in vegetation it stands a very low chance of being found. The surveyors examined a total of 21,125,000 sq. ft. in the 51 quadrats and found isolated artifacts three times in roughly 21 million tries. By contrast, using shovel probes they found individual artifacts two times in 102 tries (excluding the other eight sites). If the shovel probe results are representative, they indicate the magnitude of error if reliance is made on pedestrian survey alone for site discovery.

The other 26 sites are described as lithic sites or lithic scatter sites, indicating that two or more stone artifacts were found at

locus but that artifact densities were low. Of 26 such sites, nine (35%) were found by shovel probe. It may be the case that the sites found by shovel probe were the least dense among them, but in light of the fact that three of five find-spot discoveries were made by pedestrian survey, this is unlikely. More likely, the lithic sites reflect a range of densities, and that chance played a role in whether the site was discovered by pedestrian or shovel probe survey.

If this simplifying assuuption is made, along with the additional assumption that the shovel probe samples were generally representative, House and Ballenger's work indicates that a minumum of 35-40% of the prehistoric sites present were being systematically missed by an extremely intensive pedestrian survey. Considering that the shovel probes in the quadrats amounted to only 1/20,000 (0.005%) of each quadrat at best, the number of sites that might have been found by a more systematic test probe program might have been much higher, although the number of surface-visible sites in the quadrats is probably not much higher than was actually recorded due to the pedestrian survey's high level of intensity. There is reason to suppose, then, that more than 50% of the sites in the intensively surveyed quadrats were missed, and the actual percentage might be far higher.

House and Ballenger (1976:52) provide some data on the time and labor expended in their testing program. The survey of each 9.7 acre quadrat through generally extremely heavy brush took an average of two person-hours with a range of one to five person-hours. The purpose examination of each stream crossing took an average of 30-45 minutes of labor. The excavation of each shovel probe, the examination

of the excavated soil and backfilling took 15-20 minutes of work.

In evaluating their field methods, House and Ballenger (1976:60-62) asked whether the excavation of one or two 1 $m.^2$ shovel probes in a quadrat of 39,000 $m.^2$ area provides a reliable means to determine the presence or absence of sites. They find that it obviously is not. Shovel probes are capable of detecting sites and individual artifacts, and the fact that they found a number of low-density concentrations indicates that they chose a useful sample size for their region. However, the tiny size of their sample fraction is such that they have no statistically reliable way to estimate what they missed. Thus, while their testing program augments the pedestrian survey, they have no idea as to how well they corrected the limitations and biases of the pedestrian sample.

They were concerned at the time of their study with the adequacy of the sample size: the 1 $m.^2$ shovel probe. To test this issue empirically, they sank five shovel probes within a fairly rich known site (38-FA-100), which had been discovered when the movement of heavy machinery exposed artifact-bearing soils in several places. The five pits were spread along a N/S transect across the artifact-bearing terrace at intervals of 10 to 50 ft. They also surface-collected a "control" area of 600 $ft.^2$ in the presumed center of the site. None of the test pits yielded cultural remains below six in. depth in this case, so the volume of each test was about 0.15 $m.^3$.

Of the five shovel probes, one was completely devoid of cultural remains, and the only remains in the second was the occurrence of 9 gr. of firecracked rock. A third unit contained seven flakes,

one chunk of silicacious material, and 338 gr. of firecracked rock. The fourth unit contained nine flakes, five chunks of silicacious material and 20 gr. of firecracked rock. The fifth contained a projectile point, 16 flakes, six chunks and 911 gr. of firecracked rock. By contrast, the 600 ft.^{2} control area that was surface-collected contained one projectile point, two biface blanks, three retocuhed flake tools, one unifacial tool, 40 flakes, 20 chunks and 487 gr. of firecracked rock (House and Ballenger 1976:62).

These data indicate that their site was internally varied rather than uniform, as well as fairly rich for a lithic scatter. The figures also allow some sorts of comparisons of artifact density. The surface collection area covered about 112.5 m.^{2} and had an aggregate surface density of about 0.5 artifact/m^2 (including chunks) and about 4.3 gr./m^2 of firecracked rock, or one small piece. If meter-square surface collection units were laid out on this site, the odds are that only half of them would have contained recognizable cultural remains. This is significant for the use of a transect technique, since the use of intervals of 10-20 m. between units means that in most cases only one or two units would fall on a typical small, low-density lithic scatter, so a surface collection sampling strategy for even this rich a site would not offer a high probability of discovery. However, even though one of the five shovel probes proved sterile, 80% of the units yielded discoverable cultural remains. The artifact count per unit (including chunks) ranged from zero to 23 with an average of 9.0, and the firecracked rock ranged from zero to 911 gr. with an average of 255.6 gr. At this particular site, the shovel probes proved 18 times more effective for site discovery per square meter of surface area than did surface

collection, in spite of the fact that the artifact-bearing deposit was not more than 15 cm. deep.

Other investigators have also made effective use of shovel probes. For example, Michael B. Collins (personal communication, Lexington, 1980) recently surveyed over 20,000 acres at Fort Knox, Kentucky, in which 19% of the prehistoric sites found were discovered through shovel testing. He reports that, ":...with respect to site location, the shovel testing technique is by far the most practical, cost-efficient and successful technique compared to raking and auger boring and pedestrian survey."

Thomas R. Hester (personal communication, San Antonio, 1980) uses shovel probes when ground surfaces are obscured. He generally tests along transects laid across likely site locales. His crews use the technique in situations of recent allivial deposit as well as where heavy ground cover obscures the surface. For example, Kelly and Hester (1976) used shovel probe to evaluate sites discovered through pedestrian survey at Upper Cibolo Creek watershed in central Texas. Brown (1977) used shoevl probes to survey proposed alternate rights-of way for roadways at Olmos Dam, San Antonio. Hester (1979) used shovel probes to test along a proposed pipeline route near Victoria City. Kelly and Highley (1979) used shovel probes on the Jackpump survey in Karnes and Gonzolez Counties, Texas. T. Kelly (1979) used shovel probes in a survey in Webb County at the Palafox Mining area.

In New England, shovel testing or probing has been in use for a number of years. According to Douglas Jordan (personal communication, Storrs, 1980), shovel probing is needed not only because of surface cover, but because much of the land (50-75% in many areas) has been

plowed for generations and has been intensively collected, so that even with a visible surface the absence of surface artifacts is not a reliable indicator of the absence of sites. Sites there are often small, and have left only ephemeral traces in a soil that is acidic and excessively rocky, making such techniques as soil chemistry sensing not as useful as elsewhere. The use of shovel probes is a standard procedure in many institutions, and it is typical to expect sub-surface, concealed sites to occur.

Robert Bonnichsen (personal communication, Orono, 1980) reports that shovel testing is the only technique he has found to work reliably for site discovery in forested areas. In his region vegetation typically is mixed hardwood with a dense forest mat, making surface observation effectively impossible. Previous knowledge indicates that sites are concentrated there along fossil beaches, so Bonnichsen uses a transect technique to test at regular interavls along fossil beaches. He uses a standard shovel probe about two shovel blades wide (20 in.^{2} or 50 cm.^{2}) at intervals of 20 ft. He found that his chances of finding low-density sites were far better with a test of this size than with using a probe one shovel blade wide, because most of his sites are low in artifact density. Using this approach, Bonnichsen has been able to learn that there is a strong correlation between site distribution and the occurrence of lithic sources in nearby rocky outcrops.

James B. Stoltman (personal communication, Madison, 1980) has come to rely on shovel probing in areas of heavy vegetation, and typically uses a 15 m. interval between probes along transects. He found that screening the probe backdirt improves artifact recovery just as in excavation, so that the extra time expenditure, while

costly in time, is justified.

Stoltman tried one test of shovel probes at a site covering an area of 500 X 400 m. in which he had already surface-collected 30,000 artifacts. He placed a half dozen shovel probes into the site and all were sterile. A distribution of 30,000 artifacts over 200,000 $m.^2$ represents an average density of one artifact per 6 2/3 $m.^2$ ($0.16/m^2$). The probability of a 30 cm^2 unit striking an artifact with this density is very low -- about 1 in 75. Under the circumstances, it is entirely expectable that a small number of probes should be sterile. It could also be noted that the tests were made <u>after</u> surface collection had removed 30,000 artifacts, reducing the chances that subsequent searches would find more. Stoltman concludes by noting that shovel testing has led to the discovery of sites in prairie settings that would not have been discovered otherwise, but it is still unclear waht remains are being missed through the use of this technique.

Donna Roper (personal communication, Columbia, 1980) has begun to use shovel probes in survey in Missouri, as at the Truman Reservoir. She uses the technique in accordance with ground cover situations: where surface visibility is high, shovel probing is not used. Where it is used, she tests at 20 m. intervals along transects. Although her data are not yet quantified, she has discovered low-density sites by this means that were not discovered by pedestrian survey.

Jack Schock (personal communication, Bowling Green, 1980) uses shovel probes to test for sites along ridges or in other obscured surface areas where a high probability for site occurrence is predicted. He uses a probe size of about 30 $cm.^2$ and examines fill for continuously distributed variables as well as artifacts. Many users

rely principally on the recognition of artifacts in shovel probes, mainly because in their areas most sites lack other indicators in any quantity. This situation varies from place to place, however, so the attributes expected must be defined for each situation.

Keith McBride (personal communication, Storrs, 1980) has been using a shovel probe technique to test for sites in an area of 200 sq. mi. in eastern Connecticut, encompassing several heavily vegetated environments: floodplains, valley floors, wooded slopes and hilltops, and ridges. They tested auger holes as well as 40 cm^2 shovel probes using grids and transects with 20 m. intervals. They also used soil chemistry tests, which will be discussed later. In their experiments with augering known sites, the augers revealed site-diagnostic data only about 50% of the time. This may be partly due to the fact that they used a 4 in. auger rather than a 6 in. one, meaning that the surface area of the test hole was about 1/12 sq. ft. rather than 1/5 sq. ft. McBridde reports that his test shovel probes had far higher success rates, as one might expect given the fact that a 40 $cm.^2$ unit has about 19 times the surface area of a 4 in. auger hole. He has found many hidden sites using shovel probes with a 20 m. interval. However, he points out that many sites are only 3-4 m. in diameter, so that the technique may well miss many sites due to the sites falling between probes. The answer, he feels, is to increase the sample fraction by reducing the interval between probes.

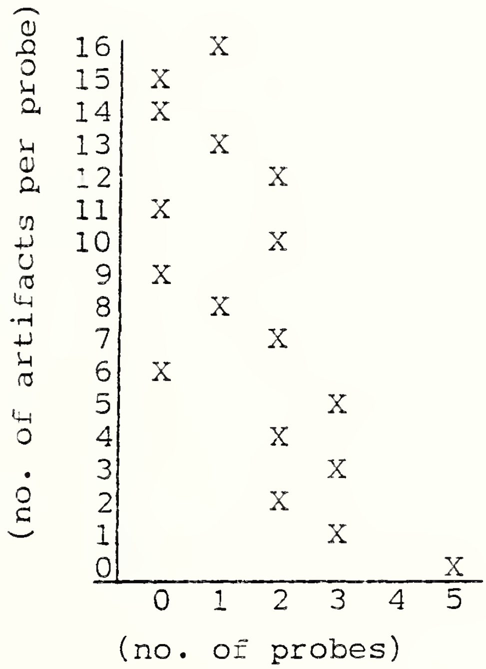
John Keller (1980) conducted a survey in some pine uplands of central Louisiana, using pedestrian techniques, before a timber sale. After the timber sale and harvest he repeated the survey,using shovel probes on transects as well as pedestrian survey. Before the

harvest he found no sites; afterward, he found 61 sites, about half because timber harvest had removed a great deal of obscuring vegetation, and about half because of the shovel probes. This project illustrates, among other things, not only the magnitude of vegetationa factors in obscuring archaeological remains, but even the inadequacy or limitation of pedestrian survey under improved conditions.

Lovis (1976) used shovel probes in his survey of the inland waterway area of northern Michigan. His study is widely available and does not need to be repeated here. Although the large interval distance he used (100 yds.) allowed small sites to be missed, and although he was sampling points within quadrats rather than quadrats as wholes (Nance 1979), his work is valuable here because of the demonstration of the sites that would have gone undiscovered if he had relied on pedestrian survey alone. Mueller (1974), too, used a 100 yd. interval between shovel probes, and some archaeologists feel that such a wide interval skews the results in favor of the discovery of large sites. Lovis used a shorter interval in later projects, such as the study he did of exchange sale tracts for the Huron and Manistee National Forests in Michigan (Lovis, Martin and Noble 1976). There he used a 50 yd. interval with 1 X 1 ft. shovel probes, and the average size of site discovered was smaller than in the inland waterway project. However, this result may have been due to the nature of the archaeological record, so controlled comparisons would be useful.

The patterns of expected probe yeilds are still unclear to surveyors. Earlier we reported a pattern from an auger test program. James Cleland (1978, personal communication, San Diego, 1980) reports a series of within-site tests at a lithic site in

Virginia, which is of interest because the site is less rich than others reportd as testing locales. He placed 27 shovel probes at randomly selectd locations around a site measuring 80 X 90 m. Each test was 50 cm.^{2} by 20-25 cm. deep. The results can be indicated as follows:



This graph does not suggest a standard curve, but instead more nearly reflects the reality of many lithic scatters. The site has a concentration of artifacts, but it is not dense or single-centered. Cleland found that the site had artifact densities ranging from zero to 64 per sq. m. of horizontal area, with an average of 19.6/ sq. m. This data was gained by the excavation of separate test pits as controls. His shovel probes yielded an average of 4.9 artifacts per test, and 81.6% of the tests within the site yielded data. Significantly, all the sterile tests were situated on the periphery of the site. Where the surface artifact density rose above 4-5 per sq. m., the shovel probe technique proved to be a reliable site discoverer. Since his probes covered 0.25 m.^{2} in area, the inference

is that the sample size should be adjusted to the attribute density of the smallest or least dense site type that can be expected in the survey area.

Sample fraction, which is related to site diameter rather than site artifact density, also presents uncertainties. McManamon (1980), in his survey of the Interstate-88 route in New York, used a transect interval of 20 m. The sites he found had areas averaging 20 X 30 m. Some were as small as 4 X 10 m., however. While such small sites could be discovered if a shovel probe fell within them, it was also possible for such sites to fall between shovel probes. This was not the case for sites larger than 20 m. Obviously sites and features can be so small that it is not practical to search for them by reducing transect intervals. However, it may be possible to increase the possibility of their discovery in two ways: by conducting probabalistic tests by shovel probe where predictive models indicate a high probability of their occurrence, and by developing weighting factors to correct estimates of the occurrence of pehnomena whose size is too small to assure high probability of discovery under the transect interval in use (Casjens et al. 1980:8-9).

Lynch (1980) tested the use of varying probe intervals at three sites in southern Illinois: the Murphy Site, 11-SA-87a, and 11-SA-87b. At each site is was possible to calculate the expected artifact density per probe, using a standard probe of 25 $cm.^2$ by 20 cm deep, because all three sites had been partially excavated previously. At the Murphy Site, the expected density per probe was 1.14 artifacts; it was 3.47 at SA-87a, and 5.37 at SA-87b. Lynch used probe intervals of 15 m. and 5 m. at the Murphy site, and found that the probe yield changed with interval. He made 48 probes at

15 m. intervals, and 204 probes at 5 m. intervals. At 15 m. intervals the average yield was 0.25 artifacts per probe, while at 5 m. intervals the average yield was 0.895 per probe. Especially at an interval of 15 m., he found, a simple transect interval sampling scheme would run a serious risk of not finding the site, even though all samples fell within the known limits of the site.

Similar results occurred at SA-87a and SA-87b. At SA-87a, 45 probes made at 15 m. intervals yielded 0.86 artifacts per probe, and 60 probes at 10 m. intervals yielded 1.1 artifacts per probe, but the predicted density was 3.47 per probe. At SA-87b, there were 55 probes made at 15 m. intervals, yielding an average of 1.34 artifacts per probe, while 77 probes made at 10 m. intervals yielded 2.07 artifacts per probe, where expected density was 5.37 artifacts per probe.

Lynch's results are very noteworthy. In all three cases he found that the fewer the probes, the fewer artifacts per probe. This may be because with fewer probes, fewer probes fall within the richer parts of the site. Also, with fewer probes, sampling error has an opportunity to play a greater role. However, in a site whose measured density was as low as around 1 artifact per probe, he found an actual breakoff point at which the probe technique became progressively unreliable as a site indicator.

The matter of the recovery of fewer artifacts per probe than expected also deserves comment. It may be due to the fact that the estimates were based on the results of the excavation of true cubic volumes, while shovel probes rarely assume the total cubic yardage or volume claimed for them. The results might have been more informative had standard volume measures been used instead of probe

dimensions.

RAKING AND HOEING TECHNIQUES:

Some archaeologists have used garden rakes and hoes to expose ground surfaces in leaf-covered forest areas (see Theodoratus et al. 1979, for example). The technique has been used to expose transects (Scott, McCarthy and Grady 1978) across survey tracts, to expose grid squares in samples of survey tract areas (Chartkoff and Donahue 1980) and to conduct probabalistic surveys in areas of thin leaf cover (Donna Roper, personal communication, Columbia, 1980).

Some archaeologists have found the rake to be a very useful survey tool in special circumstances. It has several benefits: it is inexpensive, lightweight, easily used, rapidly used, and therefore appropriate for cross-country survey. It has a negligible adverse environmental impact. On one recent field project we found that one person could clear 100 sq. ft. of heavy forest duff in 5 min., and lighter overburden could be removed in 2-3 min. for the same area. It took as much time or more to locate and lay out such units as to clear them of surface litter. At this rate, one person could expose 3000-5000 sq. ft. of ground per day. The speed and ease of this technique means that more ground surface can be cleared and examined at less cost than by any other manual technique discussed (Theodoratus et al. 1979).

We employed raking on the GO Road project because we were forbidden to use any mechanical subsurface probes by terms of contract, although heavy vegetation made pedestrian survey unproductive, while for a variety of technical and logistical reasons various remote sensing techniques were inappropriate. Had we choice, we would have

used other techniques, at least as supplements. However, the results of raking had some positive benefits. The survey project involved, among other things, the reconnaissance of 29 miles of proposed road routes. These routes had been reconnoitered previously by pedestrian survey without the discovery of any sites (Wylie 1976). In our subsequent survey, using a 3% ground surface examination of areas selected in a stratified random sample and cleared by rake, we identified 13 sites within the rights-of-way. Two of the finds were isolated artifacts, and three more were thin flake scatters. The others were sites with more substantial artifact inventories or features such as above-ground fire hearths that were still not observed during pedestrian survey (Theodoratus et al. 1979).

The raking technique has several inherent limitations, however. Perhaps the most serious is disturbance. The act of raking scrapes the surface of the ground, and this action may carry artifacts off the surface and mix them with the raked-off leaves or forest duff. Apart from the fact that this technique may thereby damage the surface of a site, it may prevent the artifacts from being observed after clearance. This problem would be especially serious with small, low-density sites, since the removal of a few artifacts at the surface might prevent the site as a whole from being recognized. There are varying opinions on the seriousness of this problem, and experimentation needs to be done to clarify matters.

Raking also limits the observer to the actual surface of the ground. Any site that is buried even a few inches below the surface would therefore not be detected as a result of the use of this technique. It also cannot be readily used in areas of grass or heavy brush. It is best done where the ground cover consists of loose leaves, pine

needles or forest duff. Roper, for example, uses raking in the uplands of the Ozarks, where the terrain is rocky, the soils are thin to non-existent, and the ground cover is leaf litter and humus rather than true soil and sod. In such areas, she uses the rake to clear 50 $cm.^2$ areas along transects the way that the shovel is used to make probes in the lowlands. She typically uses a sampling interval of 20 m. in such cases (Donna Roper, personal communication, Columbia, 1980). Michael B. Collins makes similar use of the raking technique in Kentucky, in areas where leaf litter predominates. Where grass, briar, scrub brush or forest cover predominate, raking is less effective and shovel probes are appropriate. However, where raking is appropriate, its speed makes it a useful technique (Michael B. Collins, personal communication, Lexington, 1980). Max Pavesic (personal communication, Boise, 1980) reports similar use of the raking technique in Idaho.

Scott, McCarthy and Grady (1978) used raking in the woodlands of east Texas, mainly as a means to clear transects for the use of subsurface probes by auger. They also used raking to clear a small number of 5 X 5 m. squares. The authors do not give any data on how much area was raked except to note that raking took up only 1% of their field time over two months. They were not impressed by the technique, apparently because they found no sites through its use and did find sites by other means. However, in fairness it must be said that they did not use raking in a systematic way, so it is not known whether some sites might have been discovered if they had. Alan Skinner (personal communication, Dallas, 1980) also has been unimpressed with the usefulness of raking in northeast Texas.

The use of the garden hoe is even less common among surveyors than the use of the garden rake. In principle the use of the hoe would be warranted in situations where the forest duff was too thick to be easily removed by rake, or where a little weed chopping might aid observation. Like the rake, the hoe is inexpensive, portable, easily used and rapidly used. Like the rake, it causes the scraping of the surface, and causes even more damage than the rake to a site's surface because of its continuous edge. We made use of the hoe on the GO Road project to remove fallen bark slabs which had not decomposed into humus. Our experience was that it wasn't significantly more useful than a trowel. It might possibly prove useful in other settings, however.

No experiences have been eported with the use of hand cultivators. These manual garden tools may prove useful for the clearance of areas of thin sod in a survey of a meadow. However, a shovel may be equally or more useful in this regard.

Many archaeologists have expressed disinterest in raking as a site discovery technique. Some surveyors have found the technique useful in specific circumstances. Our view is that raking is useful in only a restricted set of circumstances, most particularly when the cover is loose and light and the soil is rocky or nonexistent. In such settings drilling and shovel probing are inappropriate but raking can be very useful. The additional fact that raking can clear large areas of ground quickly and cheaply means that much larger sample sizes and fractions can be gained in surveys as compared to shovel testing or auger drilling. Raking, therefore, should be considered as a useful technique in those circumstances.

HEAVY MACHINERY EXPLORATION:

One solution to the problem of obscuring ground cover is the removal of the ground cover. There are several means to do this. the most commonly used means in archaeology are turning the soil by plow, and digging below the surface by backhoe. A variety of other techniques potentially could be used, such as burning, grading, disking, scraping, plug removal and roto-tilling. They will be considered briefly.

Plowing:

The plowing of a field removes and turns under the existing surface vegetation, exposing soil for maximum view. Machine-drawn plows can be used in combination and can turn a number of acres of arable land per day. Lease costs are high in absolute terms (most respondants on this point cite figures of $100-200/day) but not in comparison to the cost of the same square footage of pedestrian survey at the same degree of intensity.

The advantage to plowing is that it provides a large surface of freshly exposed earth for observation, offering high visibility with little or no obscurity. If the plowed field is disked as well, and washed or rained upon, viewing is enhanced. Plowing, then, creates the maximum possible conditions for subsequent visual examination by pedestrian survey. With the use of the plow, it is possible to clear up to 100% of a study area, avoiding the need for surface area sampling. On the other hand, the plowing itself can be done in a sampling regimen, except that large samples (e.g. 10% or 25% can be totally cleared, by means of strip or patch

plowing.

Plowing has considerable disadvantages or limitations, however, as a site discovery technique. It is only sensitive to sites at or just below the surface. It causes considerable destruction to sites and environments, particularly in fields that have been unplowed before. Many areas cannot be plowed. It is impractical for use in large areas or wilderness terrain.

On the other hand, it is very effective for the discovery of low-density flake scatters or similar sites. Jensen (1977) reports this successful result at the Chico Tree Improvement Farm. James Bellis (personal communication, South Bend, 1980) reports that he has had much success with plowing, especially in previously-plowed fields left fallow, and especially if the plowed field can be left for washing by rain before pedestrian survey. Michael B. Collins (personal communication, Lexington, 1980) reports on the use of plowing of strips of land in fields as a sampling technique, with good survey results. He notes that it may be necessary to mow the strips before plowing. P.J. O'Brien (personal communication, Manhattan, 1980) indicates the usefulness of plowing as a way to test the results of other site discovery techniques. She also indicates that rain-washing markedly enhances the results of survey after plowing.

Plowing is obviously not a serious technique for massive use, but it may be very useful in restricted circumstances. Since it is best used in small tracts, it can be used as a purposive sampling technique. It also may be very useful in situations where land destruction is imminent, so that the adverse environmental impact of plowing is inconsequential.

Back hoe survey:

The back hoe is a machine that excavates large holes with a power shovel. A number of archaeologists have used the back hoe to test for sites in areas with considerable overburden overlying a past occupation surface. A back hoe can dig a very sizable hole or trench. With a shovel 1.0 to 1.5 m. wide and an extended mechanical arm, it can dig up to 6 m. deep and as long as desired. At one site on which we worked in France, the supervisor had a backhoe excavate a field with over 300 m. of trenches.

Casjens et al. (1980:15-16) report using a backhoe in New England for site discovery because it could be used to dig frozen ground. In addition, it created large-size sample units, it worked quickly, used little labor and, for the volume of dirt tested, is low-cost per unit volume.

The sample size and fraction exposed by back hoe testing do not equal that exposed by plowing, by any means, but the back hoe still causes considerable environmental disturbance and can cause considerable destruction to sites when struck. Good monitoring, say Casjens et al. (1980), can control this problem, though.

They feel that back hoes provide good profiles of trenches for the discovery of sites through stratigraphy. Our experience has shown that at least in clay-rich soils, the back hoe's shovel tends to smear the sidewalls and mask any stratigraphy. It should also be noted (ibid.) that soft soils are more easily damaged by a moving machine than frozen ones.

However, the main attraction of the back hoe to surveyors is that it is the only realistic means to test soil at depths between 1 m. and 6 m. depth, where alluvium or other factors might conceal

buried remains. Jack Schock (personal communication, Bowling Green, 1980) reports that he usually uses a back hoe when surveying floodplains, to put in tests to depths of 7-12 ft. to test for the occurrence of buried remains. Negative tests take only 20-30 minutes to complete and backfill. This spring he put in 14 such tests in 6 hours at a cost of $120. He was able to test one sand ridge to a depth of 20 ft. in determining that it did contain buried sites, while clay ridges did not. Donna Roper (personal communication, Columbia, 1980) has used a back hoe at Truman Reservoir in Missouri to test riverine alluvium deposits, and Jefferson Chapman has used it at the Tellico Dam, with good effect. Thomas Hester (personal communication, San Antonio, 1980) has used back hoes on several projects in southern Texas to locate buried sites or to test for buried sites in areas of high probability (e.g. A. Fox 1979; D. Fox 1979; Fox and Ueker 1978; Ivey, Medlin and Eaton 2977; Valdez and Eaton 1979). Michael B. Collins (personal communication, Lexington, 1980) uses the backhoe in riverine surveys to test for sites in alluvium where they might be expected but where prior pedestrian survey has not indicated the presence of attributes.

The consensus of users of back hoes is that they are useful in particular settings but not as general survey tools. Although the back hoe yields a large sample size, and collects samples from zones not otherwise readily testable, its overall sampling fraction usually must be small for economic and ecological reasons. For that reason, it has not proved to be a highly reliable site discovery tool. It is, rather, the most reliable tool available for the situations in which it is useful, and there it is reliable

enough to warrant use.

Other Machines for Site Discovery:

Some other heavy machines are of potential or realized use in site discovery, although not in common use. We will simply discuss them in terms of potential advantages and limitations.

The use of disking or harrowing as a supplement or substitute for plowing can give the advantage of improved artifact recognition. Disks break up the soil in small clods than plows do, exposing more surface and freeing more artifacts. When disking is done without plowing, however, it leaves many grass stems partially exposed, which limits visibility of the surface. Disking turns the surface to a shallower depth than plowing, revealing less but causing less damage.

Grading or scraping of a surface removes overburden entirely. Grading is done sometimes in excavation as an inexpensive way to get rid of thick overburden. The process destroys the upper soil horizons entirely. Some archaeologists have taken advantage of the movement of grading machines in construction to discover sites. Carnes and Dickens (1979) discovered more sites during their environmental impact study of the MARTA rapid transit lines of Atlanta by following construction machinery than by any other method. Some of the sites they discovered in this way were very modest in size, proving that it is possible to use the approach to discover a wide range of sites. Tom King (1971) was able to do a detailed analysis of a prehistoric cemetery exposed by grading by mapping the occurrence of features as the grading machinery exposed

them.

The roto-tiller is not yet in wide use as a site discovery technique, but it offers several advantages. Garden tillers are inexpensive compared to modern tractors, and cut to shallow depths (6 in. or 15 cm) so they are sensitive to surface sites but do not produce such adverse impacts. They are useful for removing field plants or meadow grass, but not heavy brush, and are not useful in rocky soil.

Thomas (1980) reports the use of a 5 hp. roto-tiller in the Oachita Mountains of Montgomery County, Arkansas, to test five shallow, low-density sites in cases where ground cover obscured the sites' surfaces. The roto tiller proved to be light, easily operated by one person, and, because it was self-propelled, it was quite maneuverable. It cut the soil to a depth of only 10 cm. and was able to cut through humus, duff and root mats. It was able to till specifically designated sample areas so it could be used for quadrat and transect clearance. Thomas found that observation was enhanced after rainfall. He gridded his sites into 5 $m.^2$ units and selected 10% random samples on each for tilling and collection. The collections were evaluated against small numbers of stratigraphic test excavations dug at each site. The results were much more favorable than plain surface collection without roto-tilling. This indicates that the tool may be practical for site discovery as well.

Tree planters are truck-mounted devices that cut large plugs of soil (up to 2 m. diameter) out of the ground to permit the planting of mature trees or their removal by the roots. These powerful hydraulic devices are capable of removing large samples of soil to depths of up to 2 m. They can be used like back hoes

to test for the occurrence of site attributes along transects or grids. Working at its effective depth, a tree planter removes a large-volume soil sample more rapidly than a back-hoe can because of its larger cutter. The sheer size of the sample may inhibit the careful examination of the excavated soil, however.

Burning:

When heavy ground cover is removed by fire, and rain subsequently washes away the soot and ash, conditions for site discovery may be considerably enhanced. This was the experience of the U.C.L.A. Archaeological Survey after the Bel Air fire of 1962 and the Malibu fire of 1970 in the Santa Monica Mountains, after which a number of sites were discovered when previous pedestrian surveys had missed them. We do NOT advocate the deliberate use of fire to remove annoying plant cover, for obvious reasons. However, in many forest areas controlled burning is used as a management technique. Coordination of such burning with archaeological survey may result in improved site discovery.

COMMENTS ON MECHANICAL SITE DISCOVERY TECHNIQUES:

We have reviewed a series of mechanical techniques for site discovery, ranging from drilling holes and digging pits to using heavy machinery. While the discussions make their own points, we would like to make a few general comments. First, some investigators have begun to test alternate techniques, so some comparative data are becoming available (e.g. Claassen and Spears 1975; DePratter 1976; Ives and Evans 1980; Ives and Garrison 1977). They indicate that there is no most productive technique for all situations, as

is expected. In particular settings some work better than others. Each technique is sensitive to somewhat different ranges of attributes. Different techniques provide different kinds of samples, with different effective sample sizes. Each technique must be evaluated in terms of the context to which it is applied, rather than in general terms.

We can also point out that while the use of these techniques is invariably more costly than the use of pedestrian survey alone, their use can also be more cost-effective than pedestrian survey. This refers not only to their greater abilities to discover sites, but also to the consequent avoidance of the need to stop construction to salvage remains discovered after pedestrian survey indicated their absence. Of course, no sampling technique is perfect, and some cases will invariably arise when unexpected remains are encountered. However, the reduction of such incidents is economically desirable as well as scientifically desirable.

The use of such techniques, however, tends to be practical mainly with large-scale projects. As we have noted earlier, technique costs are often not reducible infinitely, and budgets must be at large enough levels to permit investment in cost-efficient procedures. Shovel testing and hole drilling are exceptions, in that they are low-cost-per-unit techniques, but they require substantial sample fractions for peak effectiveness.

Finally, we note that the difficulties which some researchers have had with particular techniques seem to stem at least as much from the use of inadequate sample sizes for the sites or concentrations at hand as from limitations inherent in the techniques. It seems to

be the general case that when sample size is adjusted to attribute density, technique productivity becomes more adequate. However, it would be a mistake to evaluate such techniques on the basis of discovery rates alone. Equally important are the failure rates. The best measure of a technique is its ability to discover remains that it should encounter. That is why pedestrian survey has limits to its value, and it is the measure by which other techniques should be judged. After all, some areas should be poor in archaeological remains, and sampling techniques should yield largely negative results in such cases. This is not a criticism of the sampling technique, for in such cases it operates as it ought.

REMOTE SENSING TECHNIQUES

Another array of techniques are generally known as remote sensing techniques (e.g. Avery and Lyons 1978; Lintz and Simonett 1976; Reeves et al. 1975). This term covers a wide variety of techniques which share in common the reliance on non-mechanical means of exploring archaeological deposits and recognizing their occurrences. In general, remote sensing techniques sense different attributes than mechanical techniques, as well as operating by means of different principles. Only one of the approaches, aerial photography, makes use of the visual medium of attribute recognition, and even it uses different principles and and identifies different attributes than mechanical or pedestrian survey techniques.

There have recently appeared a number of publications and reports dealing with various aspects of remote sensing (e.g. Clark 1975; Colwell 1970; Gumerman and Lyons 1971; Gerber 1980; Lyons and Avery

1978; Morain and Budge 1978; North and Svehlak 1977; Trubowitz 1973). Although remote sensing techniques are not yet in wide use among surveyors, a body of experience with several of them is being developed, and it is possible to evaluate them comparatively. Our purpose is not to describe how these techniques work, for in each case the task is lengthy and is better done in existing literature. Instead, we will consider the relevance of different techniques for site discovery and recount some experiences with the technique.

In organizing this material, we have divided the techniques into three major groups. Soil chemistry techniques are those which use chemical analyses or similar means to characterize the soil where archaeological remains might occur. Soil physical analyses rely on physics principles to characterize such soils. We have combined airborne radar and aerial photography with satellite-borne equivalents in a third group even though clearly they rely on physics and chemistry principles. Again, while our classification is not logically tight, the issue is not so serious as to pose meaningful problems.

By way of introduction, we would note that all remote sensing techniques do one thing in common: they identify anomalies at the surface of the earth. The anomalies are of different sorts, but in each case the goal of the technique's use is the discovery of a pattern of distribution of some phenomenon sufficiently distinctive as to indicate that it was of cultural rather than non-cultural production. In principle this is no different than the goal of a pedestrian surveyor to find a piece of rock so distinctively fractured that it would not likely be the work of non-cultural

processes.

SOIL CHEMISTRY TECHNIQUES

The various chemicals of nature occur in soils around the world to varying degrees. In some circumstances, concentrated human activities can cause the amounts of particular chemicals to become concentrated, or sometimes eliminated, from a particular spot to degrees beyond the level normally expected. When such an anomaly is detected, it may indicate the existence of an archaeological site or concentration of archaeological remains. In principle, a large number of chemicals might be so sensitive, but for both pragmatic and theoretical reasons archaeologists have not yet found that very many chemicals are meaningful site indicators (Cook and Heizer 1965; Hassan 1978). The principal chemicals or chemical compounds found to be sensitive to site occurrence are calcium, the phosphates, and degree of acidity or alkilinity recorded in terms of soil pH (hydrogen ionization). To date, little work has been done with calcium measurement, so phosphate and pH detection reflect the principal soil chemistry measurements.

The detection of soil chemicals or compounds is widely done in agronomy, and standard methods are available (e.g. Jackson 1958; Proudfoot 1975; Tite 1972). Sampling methods are well developed in soil science and botany, where transect interval sampling is done for regional study. Archaeologists have applied these techniques to the study of variability within sites (e.g. Benchley, Greeg and Dudzik 1980; Bodner 1980; Dietz 1957; Eidt and Woods 1974; Fox and Livingston 1979; Hassan 1980; Provan 1971; Sjoberg 1976; Woods 1977). Only recently have some researchers begun to turn to the problem of

site discovery by chemical means (e.g. Eidt 1973, 1977; Sjöberg 1977; Turbowitz 1973). For studies of variability within sites as well as for site discovery, sampling on grids is used as well as along transects. There is no feeling yet about ideal intervals except that enough samples should be taken to allow for sampling error to be controlled and for statistical anomalies in values to emerge either mechanically, numerically or on display maps.

Soil pH is measured by archaeologists primarily during within-site studies. We used pH measures during the GO Road survey (Theodoratus et al. 1979) but with no positive results as the loci we were surveying apparently did not exhibit anomalous pH values at otherwise-defined archaeological sites. Fox and Livingston (1979) used pH to locate historic and prehistoric remains at Victoria City, Texas with somewhat better results, but they did so to define the parameters of a known locality rather than for pure discovery. Bodner (1980) indicates the potential usefulness of pH for site discovery, but has no examples. In general, some features of intense cultural activity, such as fire hearths, houses and burials, produce high pH readings. It is not yet demonstrated that pH maps can distinguish sites that would not otherwise be discovered, however, so the potential value of the technique is still unclear and needs experimentation.

Research is more advanced on the use of phosphate detection for site discovery. There are a variety of forms of phosphate comounds, resulting from different contributing factors. The primary sources include urination, defecation, the disposal of food wastes and human burial. The phosphate compounds most useful to archaeology tend to stabilize where they enter the soil rather than to become

distributed uniformly throughout the deposit. This fact tends to create a distribution map of high and low values, some of which may merge with the phosphate values for surrounding soils (eidt 1977). Early detection relied on a colorimeter which was qualitative rather than quantitative in its readings (e.g. Dietz 1957; Eidt 1973). However, low-cost calibrated colorimeters are now available that allow measurements of values to a decimel place in the field (Hassan 1980). This in turn allows for the delineation of areas of anomalously high values that may indicate the occurrence of archaeological sites.

Some important unknowns still affect the use of phosphate measurement in site discovery. More needs to be learned about sources of phosphates (Proudfoot 1975:98) and the behavior of phosphates once added to soils (Hassan 1980:6). It appears that some phosphate compounds are more stable than others. Calcium phosphate from bone appears to be reasonably stable in anthrosols (culturally modified soils), because it is in a mineral form, but phosphates derived from souces such as urine, feces and meat are organic forms and appear to have comparatively short lifespans as compounds (Hassan 1980:6). Such phosphates "...may be taken up by microorganisms or... may be converted to inorganic phosphorus (Hassan 1980:6)." Provan (1971:39) found in one study that about 70% of the organic phosphorus had become mineralized over a few hundred years.

Extraction techniques that allow for the isolation and measurement of different phosphate compounds (Woods 1977) and effective field quantitative measurement (Eidt 1977; Hassan 1978, 1980) have offered promise that at least some subsurface sites can be detected by phos-

phate tests (Dietz 1957; Sjoberg 1976). Some investigators have used the test in conjunction with auger borings or core drills to provide crosschecks of apparent anomalies (e.g. Dincauze et al. 1976; McManamon 1980; Thomas 1974; Thorbahn 1977). Casjens et al. (1980) used phosphate tests for site discovery in New England and found them of little use. The main problems were two: first, many sites lack the heavy concentrated anomalies that make them stand out from surrounding soils in either phosphates or pH. Second, they also found that historic sites failed to produce anomalous readings even when the activities conducted there should have done so.

So far, pH and phosphate tests have been shown to have limited use in site discovery in spite of the fact that both tests are useful for within-site studies. Apart from the several important unknowns involved, it is clear that many kinds of sites lack sufficient soil chemistry anomalies to make them detectable. Either they once had high values which have since decayed (acorn processing stations are examples), or else they never had high values (or anomalously low values for that matter) to begin with because the activities conducted there were not sufficiently great to have affected the soil chemistry measurably (flake scatters are an example). Certainly some sites have anomalous soil chemistry, but they tend to be the sites that are otherwise so obtrusive that soil chemistry tests are not needed for their discovery. The sites that most need effective detection techniques -- flake scatters, for example -- are the sort of sites least likely to be revealed by soil chemistry analysis. At this point, then, soil chemistry tests

do not appear to represent effective means to meet this need. There are, however, so many unknowns and uncertainties about the chemistry of anthrosols and its measurement that it would be unjustifiably premature to discard soil chemistry tests as a means of site discovery. Instead, what is needed is a systematic program of research, to discover better what soil compounds are most affected by cultural activites, how they may best be detected, and how detection may best be done to effect site discovery.

SOIL PHYSICS TECHNIQUES:

There are a series of geophysical techniques used to measure the structure of the soil to search for anomalous structres that might be of human origin. The principal techniques include magnetic survey, electrical resistivity, electromagnetic survey, induced polarization and soil moisture survey. The first two are the most widely used among archaeologists, and their use has been limited largely, or entirely in some cases, to the exploration of known sites for their internal features. Recent declassification of ground-penetrating radar has allow this new technique to be added to this group.

While using different principles, all techniques do more or less similar sorts of things. They measure signals sent either by themselves or broadcast by natural pheonomena, across a landscape. Within the natural range of variation of such phenomena, the existence of cultural remains of some sorts produces a series of highly structure or otherwise anomalous readings that indicate the existence of the feature. As with soil chemistry, these techniques have been in use

in other disciplines for some time, and there are standard methods fortheir use (e.g. Tite 1972).

Magnetic survey is one of the most widely used of these techniques in archaeology. It came into use about 25 years ago as a means to explore sites with complex subterranean features (Aitken 1964,1969; Black and Johnson 1962; Breiner 1965; Ezell et al. 1965; Henderson 1958; Johnston 1961, 1964; Scollar 1966, 1969). Magnetic surveys measure weak disturbances in the earth's magnetic field. Variations arise because of subtle variations in the percentages of iron oxides that occur in most soils. Structures that have been burned, such as hearths and kilns, in particular produce localized increases in the intensity of the magnetic field, as firing gives them a weak thermoremnant magnetism. Subsurface pits get filled with topsoil, which has higher magnetic strength than subsoils, so localized high points of magnetism result. Values can be measured with magnetometers, such as the proton magnetometer, fluxgate magnetometer or rubidium vapor magnetometer (listed in order of sensitivity).

A number of archaeologists have worked with magnetometers, using them to measure magnetism at grid intersection points within sites. A few have tried to use them in survey situations. Casjens et al. (1980:13) report that magnetometers can be used successfully only in restricted areas, such as outwash plains, flood plains and lacustrine or sandy beach deposits, at least in New Ebgland. The technique is not useful on most glacial deposits because granitic and mafic erratics would also show up as anomalies, and this would drown out any signals from sites. Where the technique can be used, it can find prehistoric sites which have fire pits, storage pits, organic-rich middens, buried structures, tombs and so forth. It

would not find flake scatters or ceramic scatters which were not associated with middens. Historic sites would be easier to find because they usually contain structures and metallic wastes.

George Zeimens (personal communication, Laramie, 1980) found that most of the sites in his region were undetectable by magnetometry. As with other techniques, the use of this technique must be predecated on the nature of the archaeological and environmental situation as well as on the technique itself.

Electrical resistivity is another technique that a number of archaeologists have used over nearly 20 years to explore the internal structures of sites (e.g. Clark 1969; Ford 1964; Ford and Keslin 1969; Goodman 1971; Shane 1969). It is just beginning to be explored as a discovery tehnique (Carr 1977; Pratt and Pratt 1979). Resistivity measurement relies on the conduction of voltage through the ground. Differential readings occur because of differential resistence to the flow of current between two emplanted electrodes (placed at two points on a grid). Differential resistence in turn occurs because buried archaeological features tend to have different water contents than surrounding soils and therefore have different resistences than surrounding soils (Tite 1972:25). The method can be capable of locating such buried features as pits, furnaces and kilns, which may be isolated, but it is usually most successful at locating linear features such as buried ditches, walls and roadways. Compared to magnetometry, resistivity has certain advantages, according to Tite (op. cit.). The technique is simple, the equipment is comparatively low-cost, it is unaffected by high tension lines, buried cables or other producers of magnetic

disturbance, it is unaffected by iron masses, so it can be used in the middle of towns and near modern habitations. However, it is a slow technique to implement and therefore productivity is low and labor cost is high. Its results by themselves are difficult to implement so many users use it in combination with other techniques and look for redundant anomalies (e.g. Pratt and Pratt 1979).

Electromagnetic survey uses a different principle but detects the same kinds of phenomena, such as buried metal masses (not just iron), pits walls and ditches. The system uses two electric coils: a transmitter and a receiver. The transmitter is fed a continuous alternating current. There is not direct transmission to the receiver, so voltage is usually zero. When the device passes over a buried feature, however, eddy currents resulting from the alternating field in the transmitter coil flow in the feature and induce an alternating current in the receiver coil. Variations in both magnetic susceptibility and electrical resistivity can induce current flow. The instrument is passed over a land surface along transects and readings are measured to record anomalies. The system thus avoids the electrode planting necessary for resistivity measurements (Tite 1972:32-3). Metal detectors are really variants of this instrument.

The use of electromagnetic survey is not yet widespread in archaeological survey. We used a metal detector survey in the GO Road survey (Theodoratus et al. 1979) with mixed results. It proved useful to map within sites such as a historic Forest Service guard station, but we did not discover a single site by its use alone. However, this result may have stemmed from the inadequacies of the instruments we used rather than the system itself.

Tite (1972:39-40) describes a tecbnique of induced polarization which makes use of the measurement of a transient voltage following termination of a direct current flow through the ground, and which decays to zero in a few secods. The technique detects buried features such as pits, walls and ditches, because buried archaeological features have a different water content than surrounding soils (banks have lower contents, ditches have higher), and groundwater serves as an electrolytic solution which can participate in the separation of charges in the introduced current. The technique requires the implantation of four electrodes, so it is slow and laborious. However in ideal cases it is more sensitive than resistivity so it may provide less uncertain anomalies. To our knowledge, the technique has not yet been used in archaeological survey, although some British archaeologists have used it to explore the internal structures of known sites.

Casjens (1980:14) discusses the use of soil moisture meters for site detection. The technique rests on a now-familiar principle: that buried archaeological features have a different water content than surrounding soils. They used a moisture meter to test three sites that were also being tested by ground-penetrating radar, in order to see if soil moisture readings alone could indicate the existence of sites. Their results were ambiguous but promising. They found that there weren't enough systematic distinctions between site moisture readings and off-site moisture readings to make the occurrence of a site a condition reliably indicated by the meter. However, they also found that the moisture of soils off sites tended to be more uniformly moist than site soils, which were internally highly variable. Therefore the occurrence of zones of marked

soil moisture variability might be site indicators. They felt that the technique was at least as promising as phosphate testing as a means of site detection, but that much basic work needed to be done. The equipment costs no more than a good camera, and the technique can be done rapidly, but the results should be verified independently.

Ground-penetrating radar is a recently-declassified instrument that was introduced to archaeology about five years ago (Bevan and Kenyon 1975; Pratt 1979). Its chief use has been the study of the internal structures of sites (e.g. Bevan 1979; Casjens et al. 1980; Grossman 1979, 1980; Pratt and Pratt 1979; Vickers 1979). Some attempt has been made to gauge its usefulness as a site discovery technique (Bevan 1979; Casjens et al. 1980; Roberts 1979).

The radar unit in use has two components. A sender-receiver is pulled across a tract of ground on a grid or series of transects, the unit mounted in a sled. Its signals are recorded by a stationery unit thatprovides readings. The data are plotted by computer to provide a sy-map of the tract. The radar unit measures echos in such a way as to indicate the presence of subsurface anomalies, such as refuse pits, rock alignments, buried buildings, and even buried plow scars.

Where it works, radar has the ability to detect a wide range of features, although it is not yet sensitive enough to detect individual artifacts. It is expensive to operate -- currently the cost is about $1000/day. Radar is not effective in soil of high salinity or high acidity. So far radar has trouble detecting

such prehistoric sites as shell middens, much less flake scatters. Such sites exhibit too much noise in the radar readings to allow them to be discriminated successfully from surrounding soils (Casjens et al. 1980:13-14; Roberts 1979). The technique therefore seems best suited for the mapping of the intenal structures of known sites, especially when the sites are test-excavated and radar readings can be used to extend the known data (Bevan 1979). Current research indicates that large, complex sites can be studied successfully with radar (Joel Grossman, personal communication, New Brunswick, 1980; N'omi Garber, personal communication, Philadelphia,1980). The Institute for Conservation Archaeology at Harvard tested the technique on three sites ranging from a dense midden to an unconsolidated site which had pit and heath features. They found that the technique could not successfully discriminate the sites from non-sites, but that once the sites were identified, by other means, radar could locate pit features, hearths and soil junctures in all three sites (Casjens et al. 1980:14). They therefore think the technique has promise as a site discovery tool. Obviously more work needs to be done with radar, and it may be that more sophisticated interpretive programs will succeed in the better identification of sites.

So far, none of the soil physics techniques has proved very successful at site discovery. In general, it appears that they are most sensitive to the kinds of sites which least need detection, and are least appropriate for the kinds of remains most in need of advances in detection. As with soil chemistry, however, these techniques are extremely experimental for archaeology and it is premature to conclude that they are not useful for site detection.

Rather, they represent an area in which productive research can be done to discover the utility of the techniques for site discovery with greater precision.

AERO-SPACE DETECTION TECHNIQUES:

A separate array of techniques is available for site detection. These techniques involve the use of aerial photography and airborne radar, each done from either aircraft or space satellites. The use of airborne radar is quite new to archaeology, while aerial photography represents one of the earliest uses of a technological aid to site discovery in the discipline (Miller 1957; Reeves 1936; Solecki 1957). There is an enormous literature on aerial photography, including entire books on techniques and applications (e.g. Deuel 1969; Wilson 1975) and international symposia on the subject (e.g. Alfieri 1964; Baradaz et al. 1964; Lerici 1964; Scollar 1964).

Aerial photography in archaeology rests on the interpretation of three kinds of phonemena: soil marks, crop marks and shadow marks. Soil marks are visual anomalies produced by differential water retention in the soil; buried archaeological features produce distinctive patterns. Crop marks are patterns of light and dark plant growth. Buried features produce distinctive patterns because of differential water retention. Shadow marks are shadows cast by low protruding features at sunrise and sunset. Aerial photography can also be useful to archaeologists to identify significant biotic associations. This may be done to allow stratification of a landscape for survey design (Schiffer, Sullivan and Klinger 1979). It may also permit identification of specific plants or plant associations that may be associated with archaeological sites

(Kathleen Deagan, personal communication, Tallahassee, 1980).

The range and sensitivity of aerial photography can be increased through the use of films and filters that are sensitive to narrow portions of the light spectrum, both visible and invisible. Currently, much innovative work is being done with infrared films, both color and black-white, which may be sensitive to plant growth patterns or archaeological features themselves (Gumerman and Lyons 1971; Gumerman and Neeley 1972; Scollar 1970). Useful aerial photos can be taken at low elevation, high elevation, or from satellites (Lyons and Hitchcock 1977; Lyons and Avery 1978). Some useful applications include: Aitken (1964); Badekas (1975); Beuttner-Janusch (1954); Bevan (1975); Bromley (1971); Bruder et al. (1975); Coe (1969); Deneven (1976); Ebert et al. (1979); Evans and Jones (1977); Fagan (1959); Fowler (1969, 1977); Harp (1974, 1977); ITEK (1965); Jalmain (1970); Matheny (1962); Morell (1965); Palmer (1976, 1977); Prewitt and Holz (1976); Riccio and Gazzier (1974); Schaber and Gumerman (1969); Strandberg (1967, 1974); Strandberg and Timlinson (1970); Tartaglia (1977); and Vogt (1974).

Where aerial photography can be used, it is the most cost-effective site identification technique. However, its uses are extremely delimited, confined greatly to areas of appropriate cultivation and crop growth. The site patterns it produces are therefore more artifacts of current land use than of past settlement (Scollar 1970). It is important, therefore, to understand the limitations of this technology for site discovery while acknowledging its value.

First, aerial photography cannot readily identify small, low-density archaeological concentrations. It succeeds in identification of

big, obtrusive sites and features. Flake scatters and other easily-overlooked wilderness sites do not show up with any reliability at all in aerial photographs. Second, the resolution from aerial photographs is biased against the discovery of small things, even when observation conditions are best. Aerial photographs have led to the recognition of highly discrete prehistoric roadway patterns at Chaco Canyon (Lyons and Avery 1978), and we do not mean to disparage that finding, for some kinds of sites may be found by no other means. Aerial photos may be excellent for the mapping of early logging railroad rights-of-way in the Sierras, for example, or of log flumes and hydraulic mining works. But in general, these sites are the most obtrusive ones with the least need for technological innovations in their discovery. It is to be hoped that further development will improve the discovery capabilities of these techniques, but currently they do not offer material benefits for the discovery of most of the kinds of remains which most need them.

The usefulness of airborne radar is on a par with that of aerial photography. For example, Saltus (1980) describes the discovery of a system of canals in southern Mesoamerica through the use of airborne synthetic aperture radar. The canals were features so structured, and located in so remote and heavily vegetated an area, that they were not discovered by pedestrian survey. The technique is currently rather expensive ($3000/hour), and has not yet been shown to identify features smaller than canals, but further research may yet make the technique more practical for site discovery.

COMMENTS:

The problem of site discovery is one which appears to be amenable to improvement through the application of technology. Remote sensing is currently the aspect of technological innovation most suitable for such improvement. Currently, however, this apparent promise is not fulfilled. None of the techniques appear to offer means to discover sites that would not be otherwise discovered, or would not be discovered more readily and inexpensively by other, simpler means. The application of technology is really the only means to make marked improvements in surveyor productivity and to reduce survey costs in the near run. We are therefore extremely disappointed to find no apparently breakthroughs at this time.

We note, however, that most applications of remote sensing to archaeology are still very much in the experimental stage. The potential therefore exists that some of these techniques, or other related techniques not yet considered, may prove to fill this need. Further research in all these tehniques is therefore warranted.

At the same time, the current uncertain state of these techniques means that they cannot be judged effective in specific situations the way that many mechanial techniques can. They must remain experimental and supplementary until further research delineates the kinds of remains and the situations for which they are the most effective discovery techniques. This should be a major goal of research.

IV. CONCLUSIONS

This review of site discovery procedures has been aimed to consider how site discovery procedures can be made most effective, both in terms of the reliability of discovery procedures themselves, and the costs engendered by agencies that sponsor surveys. At this point certain points can be restated in summary, and some conclusions toward this direction can be drawn.

The process of site discovery is complex, not simple, and involves the recognition of patterns of archaeological remains or attributes as they are distributed in regions. A variety of techniques is already available to achieve discovery and recognition. Each of the techniques is sensitive to certain kinds of attributes of archaeological sites or remains, and its sensitivity is greater or lesser under different conditions. No single technique is capable of being sensitive to all attributes, or is equally sensitive to a particular array of attributes in all situations. This stricture includes pedestrian survey, even though pedestrian survey is widely useful.

Archaeological survey is, to repeat Schiffer, Sullivan and Klinger's (1979:2) definition, the process of the application of a set of techniques for the discovery of the archaeological resources of a region. The design of a survey requires an understanding of the kinds of archaeological resources likely to be encountered, the nature of the environment within which the survey is to be done, and the appropriateness of different survey techniques to reliably recognize the extant remains under those conditions. Giventhis

knowledge, an appropriate survey technology can be adopted and an appropriate sampling strategy can be adopted.

One implication of these findings is that reliance on pedestrian survey as a sole site discovery strategy is rarely adequate. We want to emphasize that this conclusion is not our contribution, for our many colleagues have demonstrated it clearly and repeatedly. In many cases, probably most cases around the U.S., pedestrian survey misses a great deal of archaeological remains that can be found by other means. The inference is clear: pedestrian surveys should normally be accompanied by other appropriate site discovery procedures, and there may be situations in which pedestrian survey itself is not an appropriate discovery technique.

The use of multiple and redundant techniques can improve site discovery. Research and development of remote sensing techniques may add to the repertoire, but currently the most functional supplementary discovery techniques are mechanical in nature. Research is needed just as badly in these mechanical techniques to determine more clearly what they find and miss and how to use them most effectively. In fact, this research will provide faster, more useful and less expensive payoff than research into remote sensing.

Apart from these applications, we can suggest two other means to improve site discovery productivity: information management and simulation modeling, which are closely related.

By information management, we refer to the organization and use of existing knowledge to permit the best-informed decision-making about further research. Archaeology is a field which touches upon as many fields of knowledge as any other, from basic physics, chemistry and mathematics to history, ethnography and ecology. Even in

specific surveys, research design must take into account such factors as previously known sites, reports on previous excavations, local ethnographies and histories, area geography and geology, biotic communities and natural histories, the history of previous research and applicable anthropological method and theory. Clearly, the more effectively this information is pooled and made available, the more productive any subsequent surveys will be. Better information means better planning and fewer surprises later. Such information management is within the capabilities of existing technology (e.g. Gero and Root 1980; Doszkocs, Rapp and Schoolman 1980), but it is not achieved very systematically in archaeology. Moreover, there is a cost for the establishment of such systems of maintained information, as well as for their use. The cost, however, must be weighed against the cost of doing surveys less well than they might be done. To cite one example, it cost the Forest Service nearly $200,000 to re-do the environmental impact study of one six-mile road route in northwest California. How much does it cost to re-survey lands that have already been surveyed, but not adequately? How much does it cost to stop ongoing construction to mitigate cultural resource damage that was not discovered before construction? Clearly the cost of information management is relative, and in the long run the proper use of information may save money in absolute terms. Archaeologists can't be sure at this juncture because it has not happened very well yet.

One outcome of full information management is the development of predictive models of archaeological resource distribution, or so-called simulation models (Dincauze 1980; Hodder 1978; Hodder and Orton 1976; Ippoloto 1980; Pilgrim and Thor 1979). Predictive models

whether formal or informal allow the archaeologist to predict the kinds, distributions and frequencies of archaeological remains in an area. They not only allow for better survey design, they allow for feedback from suvey results, which permits further refinement of the model. Eventually a point may be reached at which original surveys may no longer be necessary because the occurrence of resources can be correctly predicted. Obviously no initial model can achieve that predictive power. However, models that are continuously developed and refined may eventually approach that level. When and if they do, real cost savings can be achieved because laborious surveys will not need to be done regualrly. Instead, selective sample surveys can be done on a much smaller scale to continue to test and refine the model.

If further predictve power can be achieved, it may be possible from survey and test excavation data to learn to predict the contents and internal structures of sites. If so, a new approach to site classification would emerge, one based on real formal variability. The meaning of significance would change, because it would be possible to specify empirically what sites were similar to what other sites, and to what degrees. Management programs that identified and preserved truly representative samples of sites could be developed. Mitigation needs would be affected, and other real cost savings could be achieved.

We raise the spectres of information and simulation model management because under the current organization of research, neither can be achieved. Neither private contractors nor universities have the resources to develop and maintain such programs. In fact,

the only organizations that do are the client-organizations for archaeological service, who stand to benefit most from their development. We suggest that the current relationship between client and practitioner might become much more effective with client participation in information management and model development, either as a research goal or as an administrative function for improved cultural resource management. There are various means by which such an end might be achieved. Without client participation, however, we predict that many, perhaps most, of the improvements in archaeological survey productivity will not be realized.

Yet even without such involvement, archaeological survey has made radical changes. Its complexity and sophistication have begun to rival that of excavation. The calls to arms issued by Binford (1964) and Ruppe (1967) less than 20 years ago, different as they were, have been heard and answered far beyond the limits anyone had guessed at the time. They fact that we can be so concerned about the relative merits of alternate techniques of site discovery is symptomatic of how far we have come. With a remarkable lack of self-consciousness, survey has found itself at the very center of the research enterprise in American archaeology, and should be the scene of some of archaeology's most innovative research for many years to come.

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